Assessing the impacts of glacier change in the coastal temperate rainforest

Shad O'Neel & Eran Hood
Yumi Arimitsu, Peter Winsor, Sean Fleming, Anthony Arendt
Allison Bidlack & Steve Gray

This work made possible by

AK CSC
Alaska Climate Science Center

ALASKA COASTAL RAINFOREST CENTER
INTEGRATING SCIENCE, RESOURCE MANAGEMENT, AND COMMUNITIES

UAS UNIVERSITY OF ALASKA SOUTHEAST
learn • engage • change

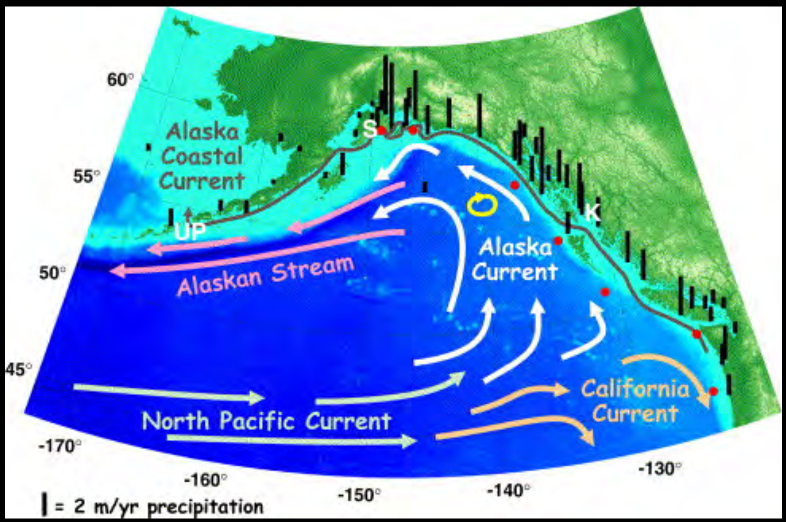
USGS
science for a changing world

NORTH PACIFIC LANDSCAPE CONSERVATION COOPERATIVE

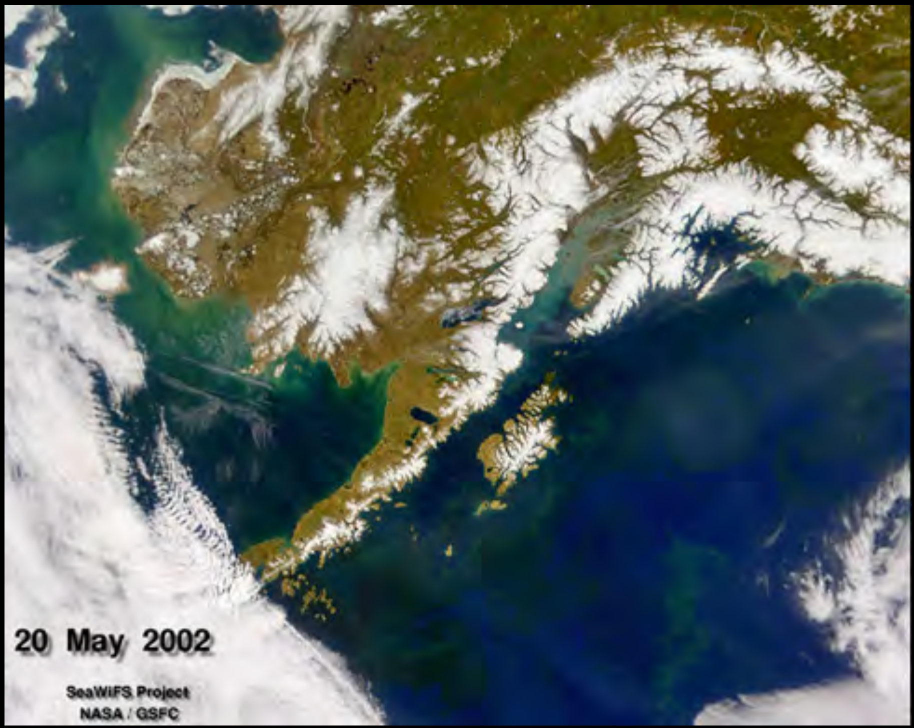
- Glaciologists, Biogeochemists
- Oceanographers, Biologists
- Hydrologists, Ecologists
- Science communication specialists
- Resource managers
- Agency managers

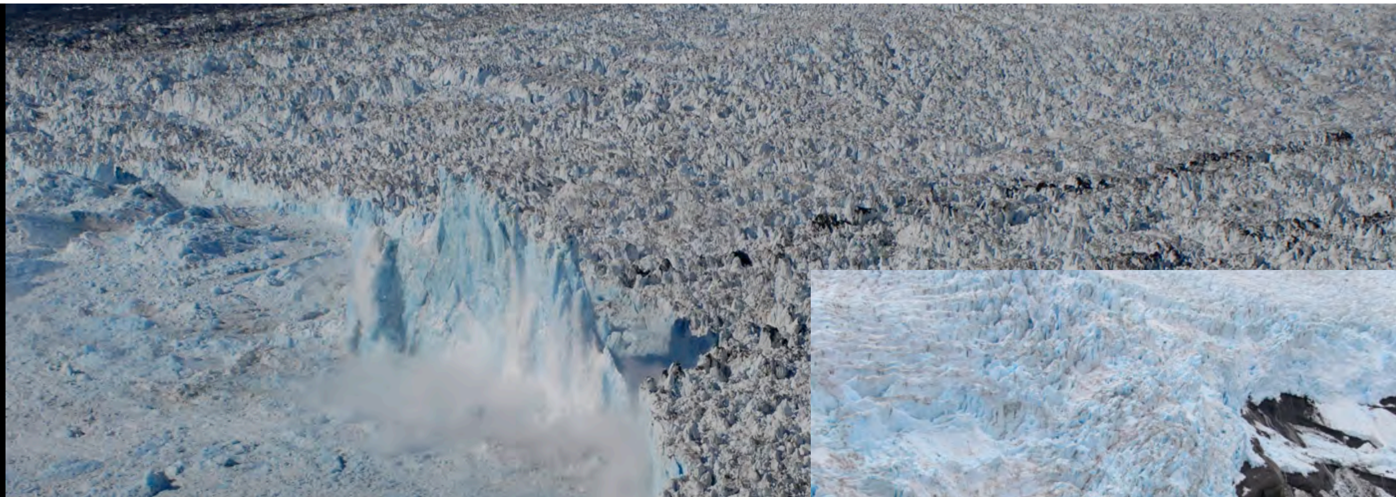
Gulf of Alaska ecosystem

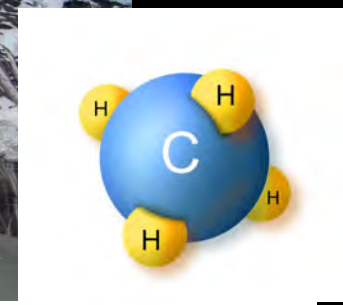
- Mean GOA precip. > 2 m/yr; PWS 4.7 m/yr
- Glacier coverage 18%, Glacier-derived runoff ~50%
- Strong ice-ocean-ecosystem linkages and feedbacks
  - Nutrient delivery, primary productivity, fish and bird populations
  - Ocean circulation, sea level change, hydropower resources

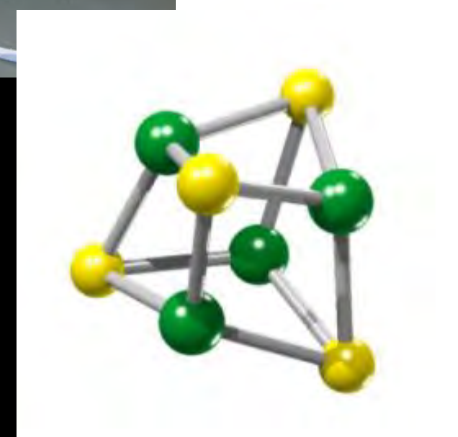


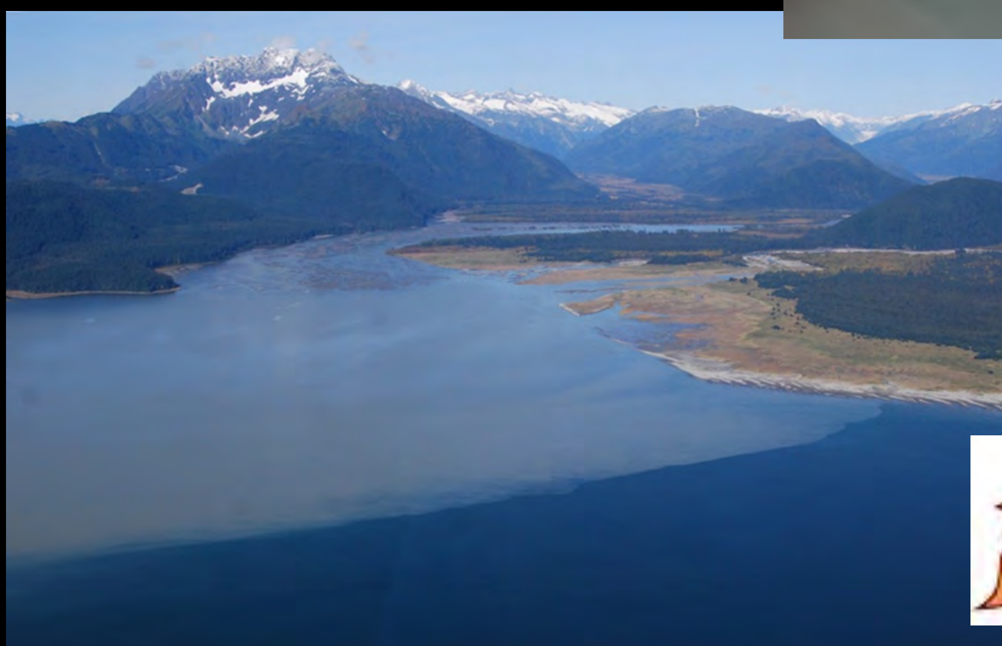
Weingartner, 2005



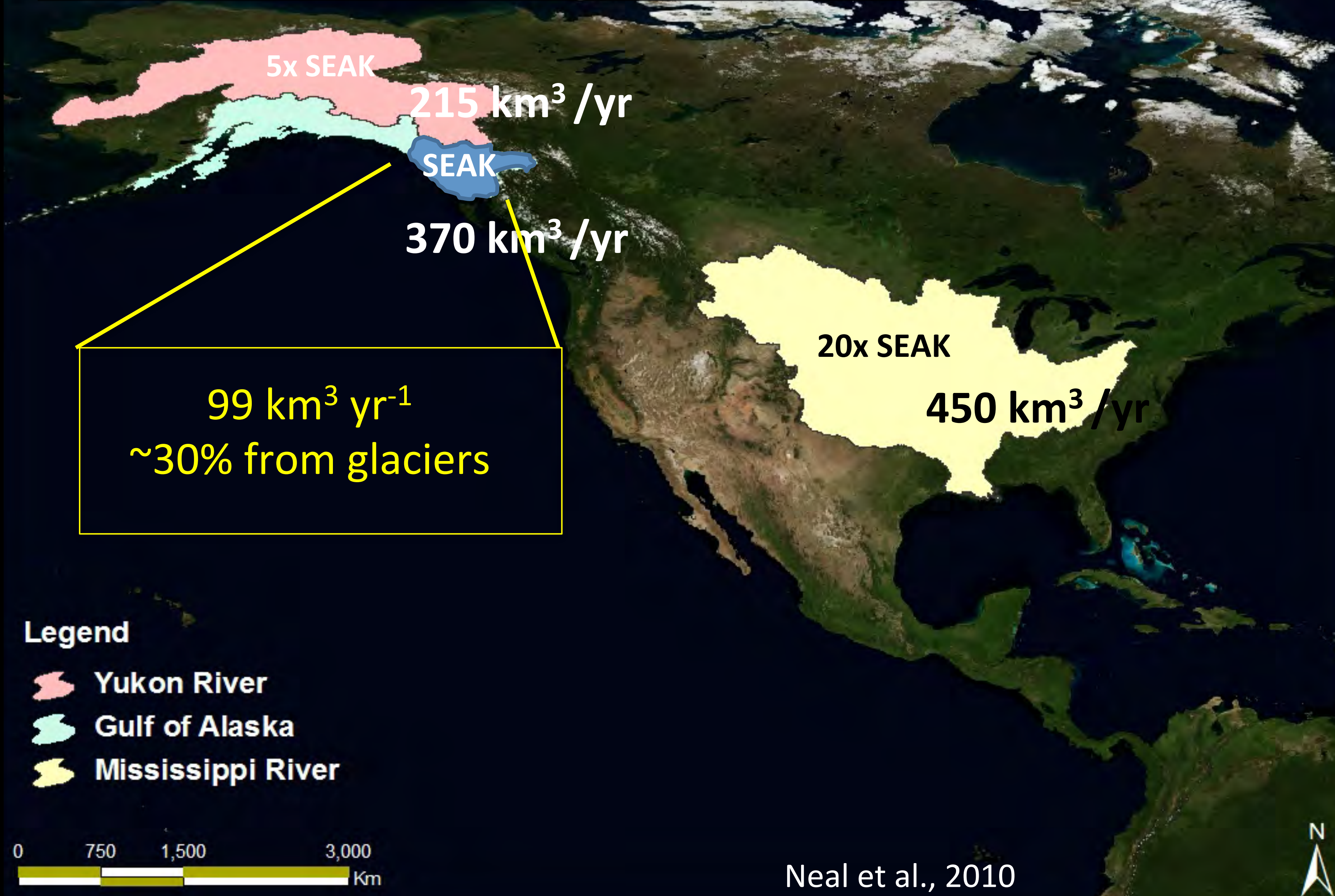



H
H
C
H
H





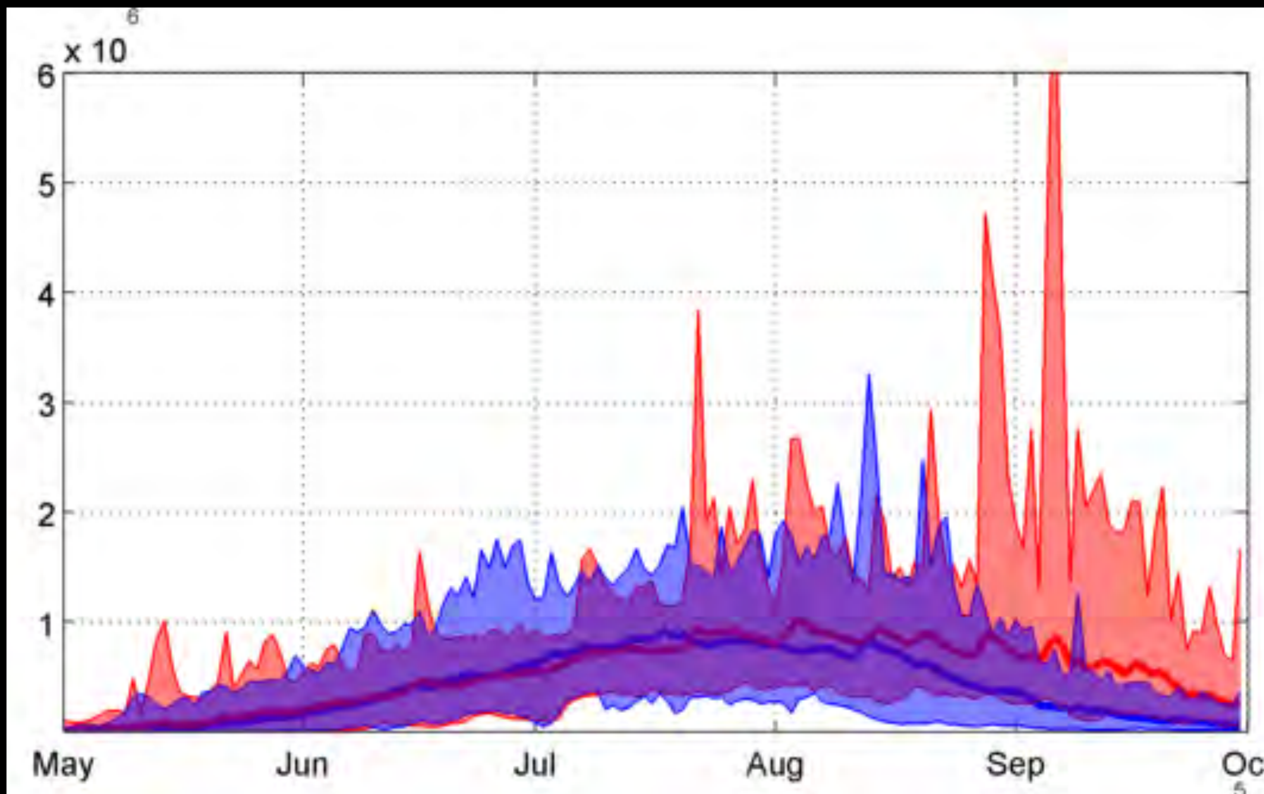
Glacier runoff



Glacier streamflow

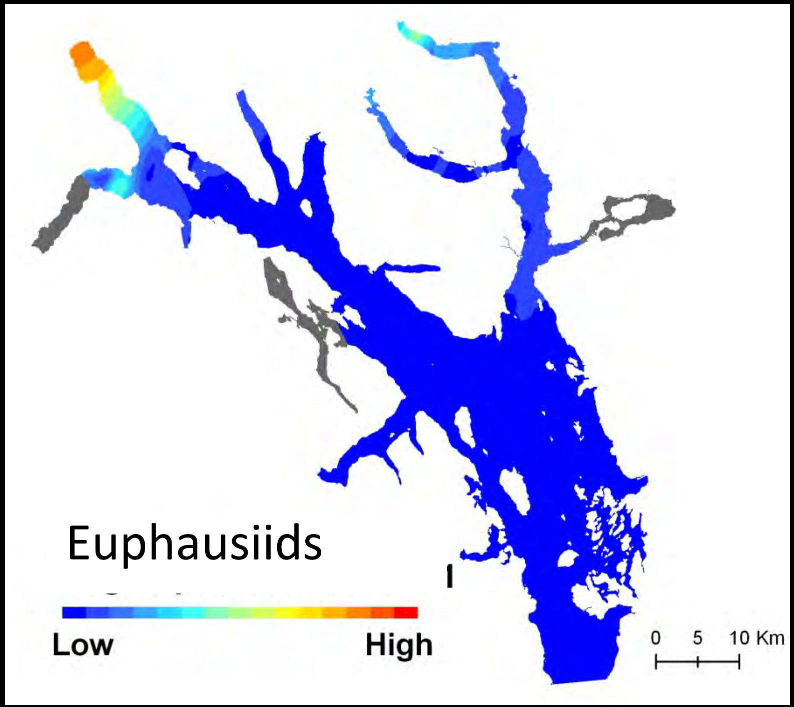
Streamflow at a continental versus maritime glacier

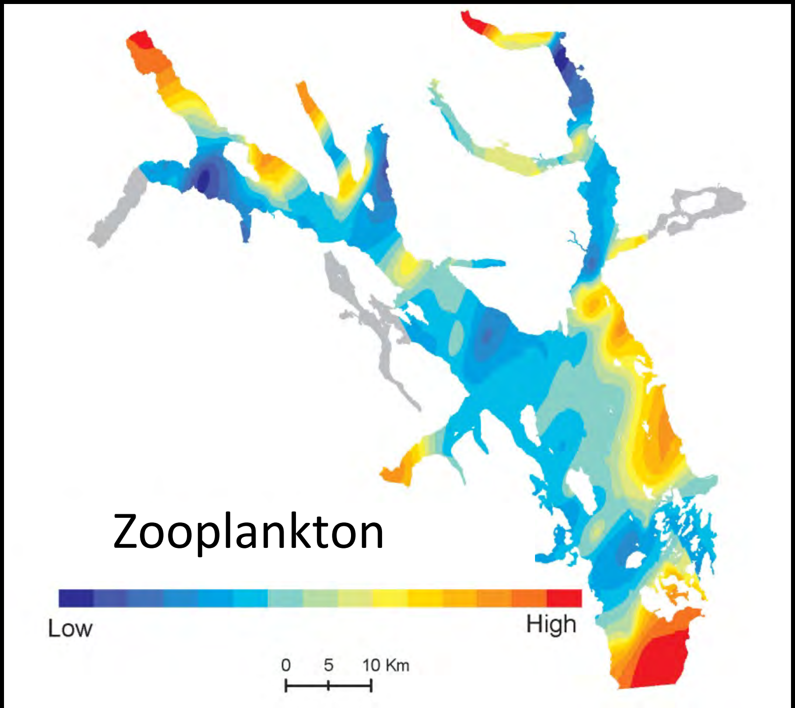
Streamflow $m^3\ s^{-1}$



Gulkana Glacier   Wolverine Glacier

Glacier Biology





Krill and plankton can thrive glacier-dominated fjords

Ice-ocean interactions

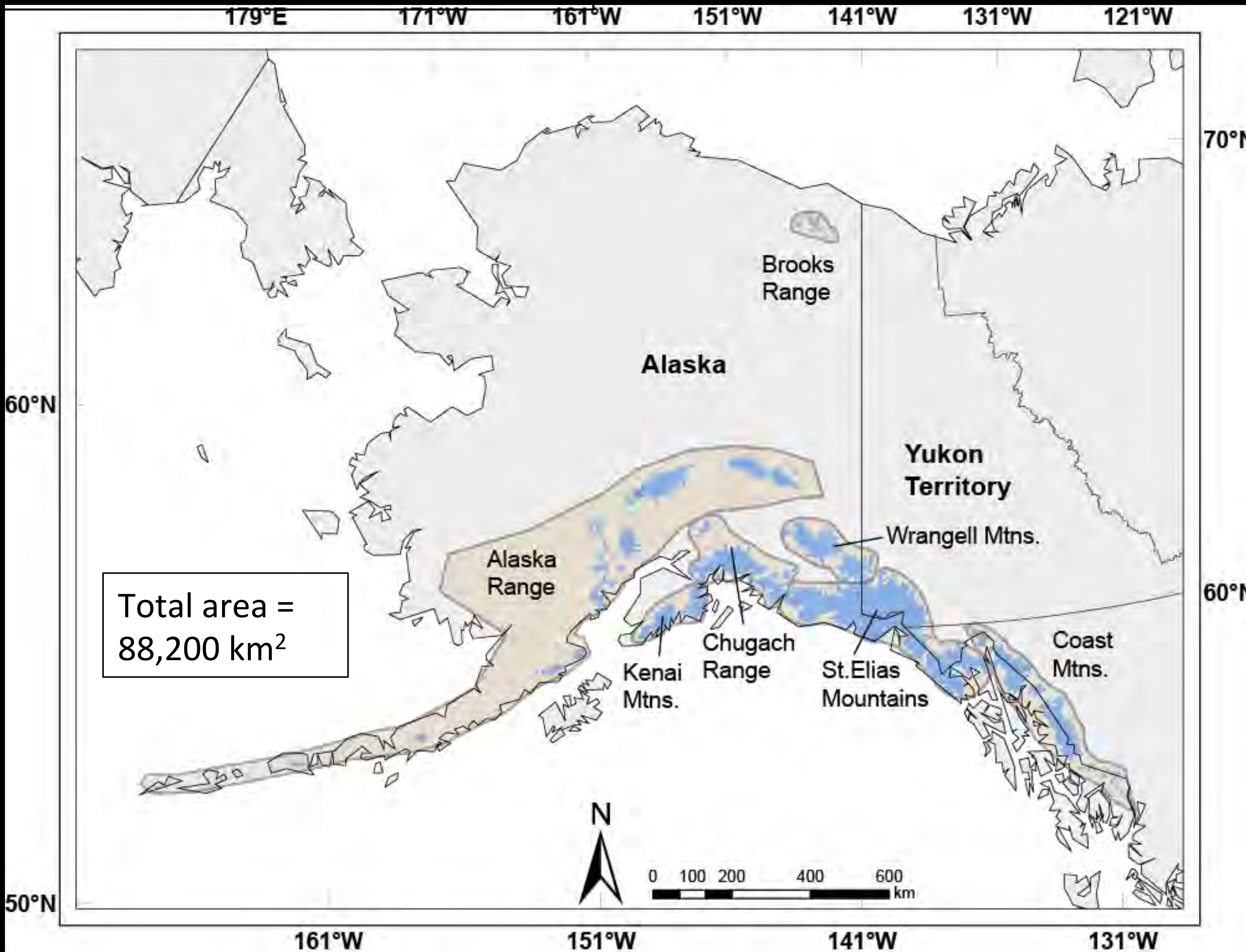
Calving glaciers are strongly coupled to the ocean

Juneau workshop: develop a conceptual model

- Evaluate physical and ecological interactions between glaciers and the coastal ecosystem
- Enhance our collective understanding of research needs related to glacier change
- Balance science and management priorities

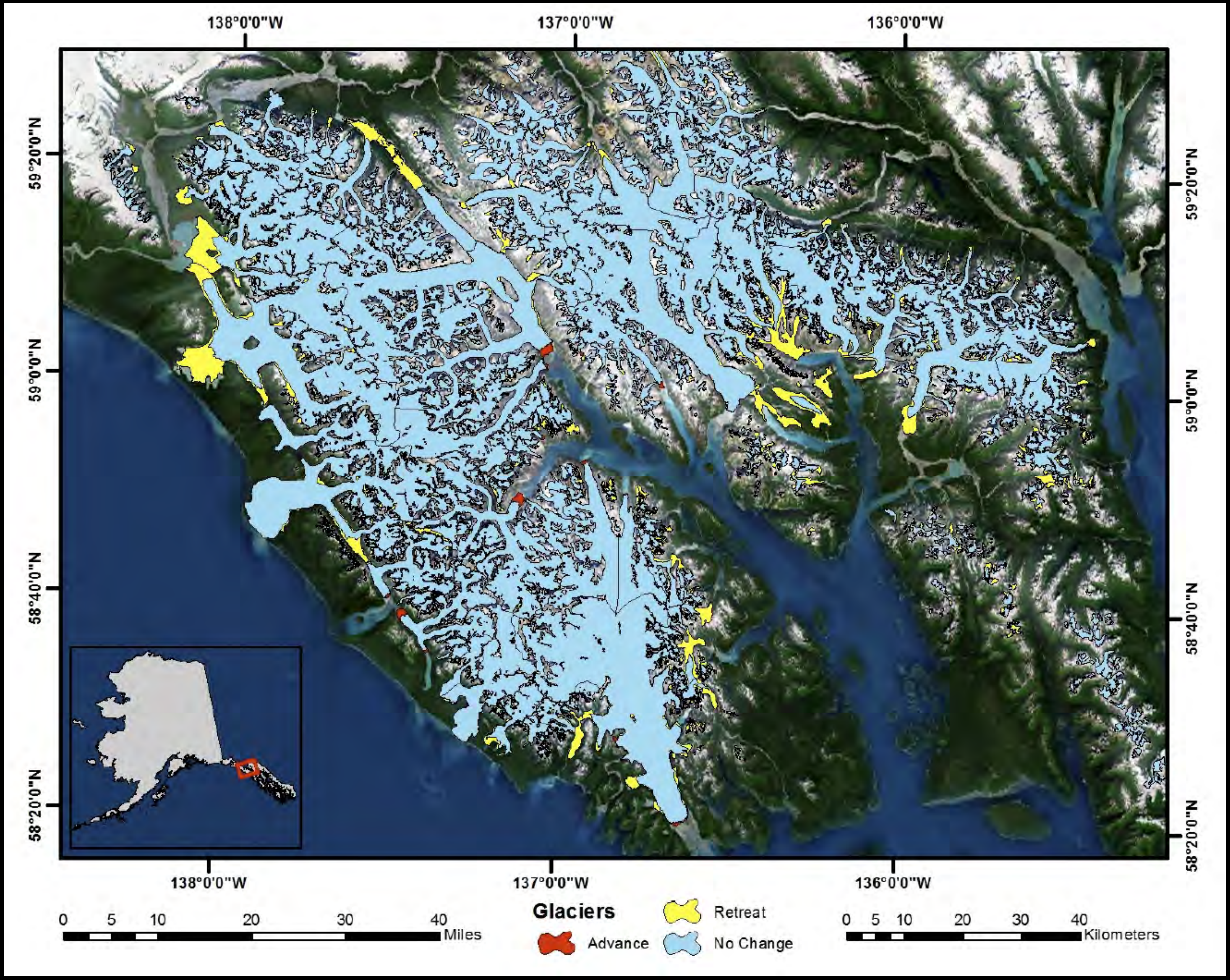
Glaciers

Alaska's Glaciers



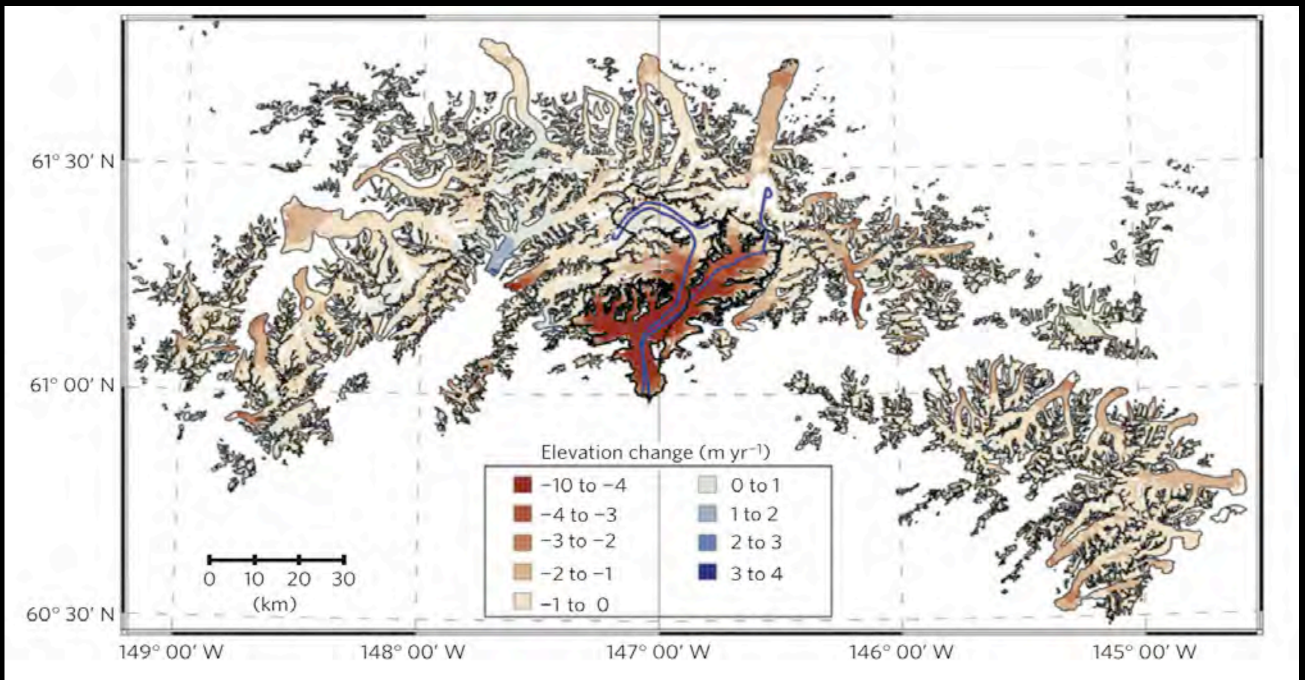
Total area = 88,200 km^2

Recent glacier changes

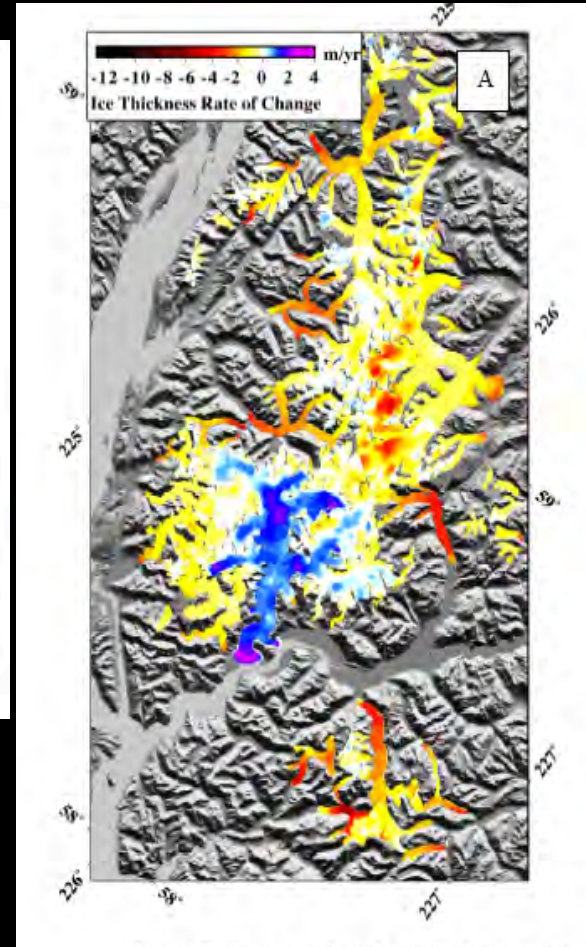


(www.glims.org/randolph)

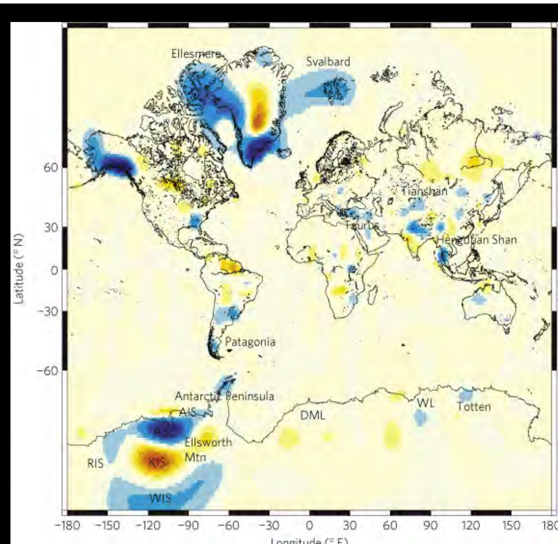
From area to volume change



Berthier et al., *Nature Geoscience,* 2010

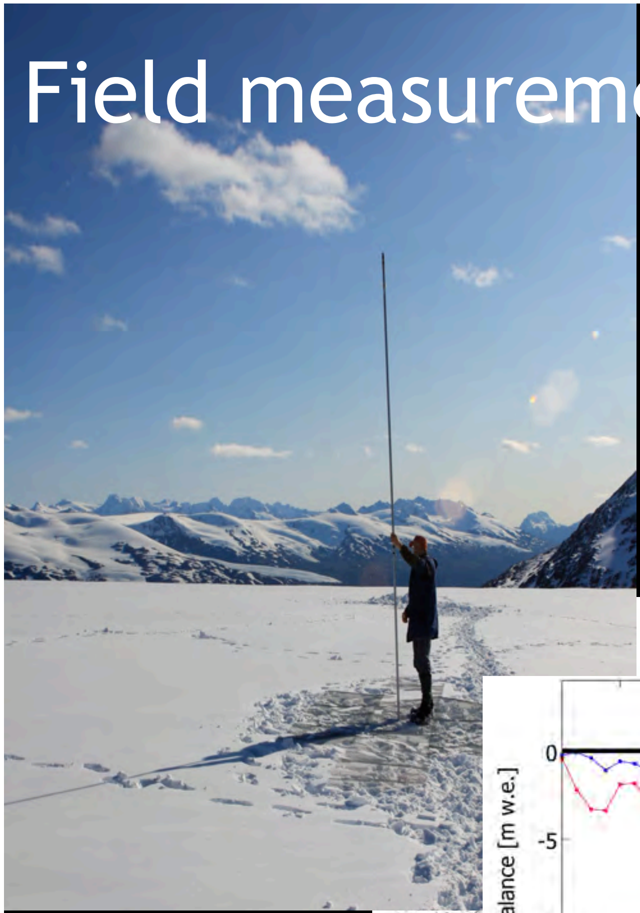


Larsen et al., 2007

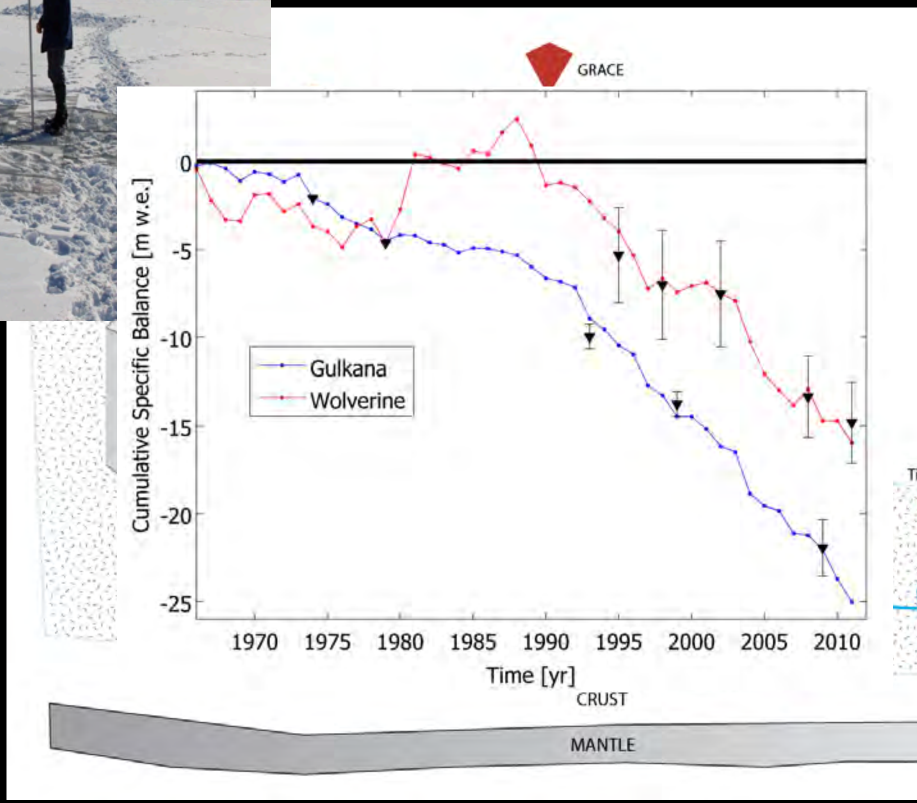


Wu et al., 2010

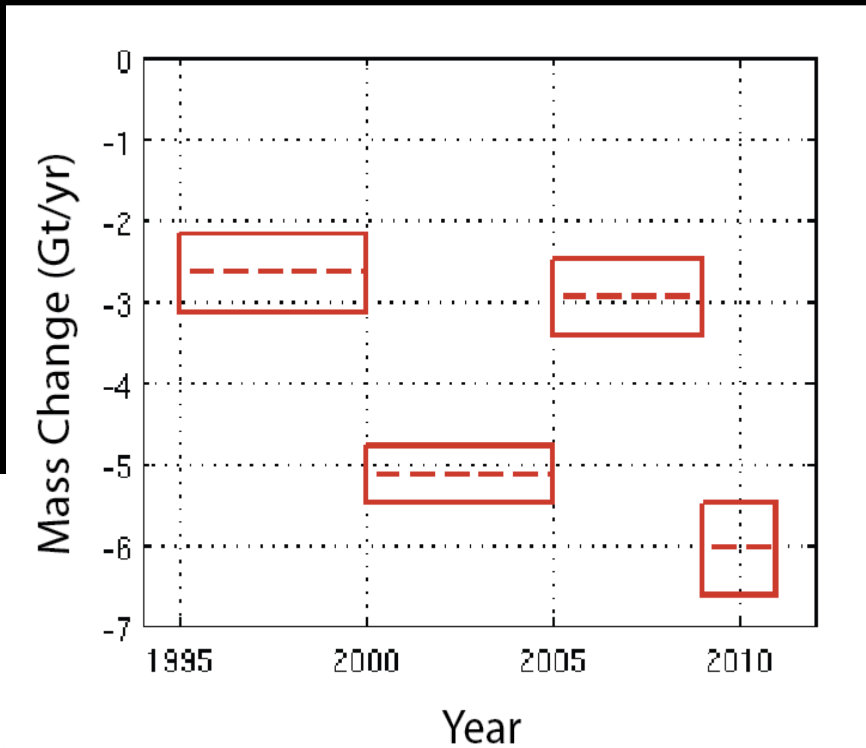
Field measurements

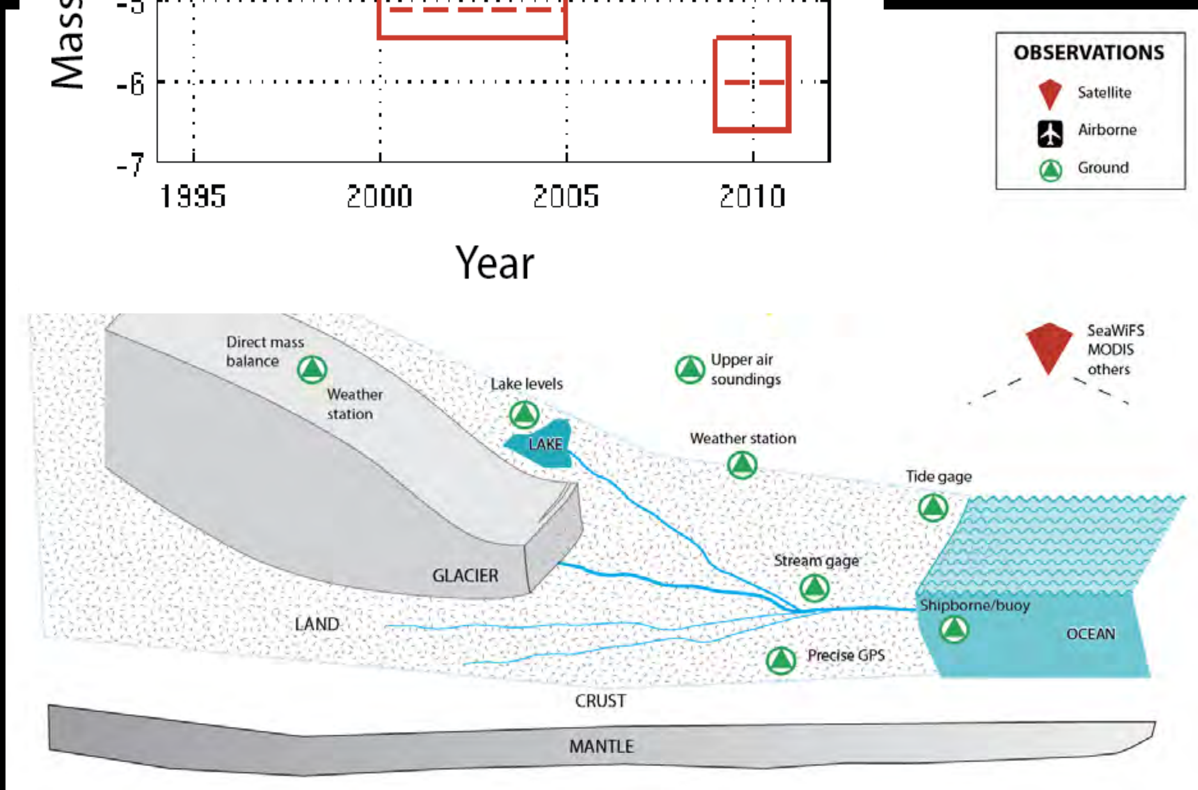


Temporal resolution: medium
Spatial resolution: high
Spatial coverage: low



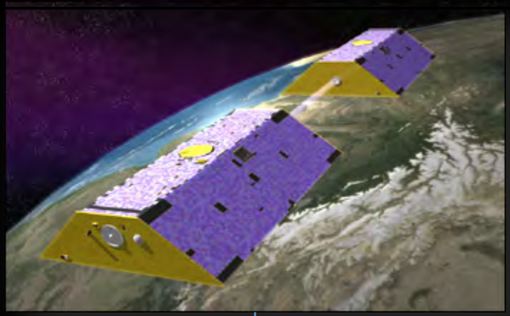
Airborne observations

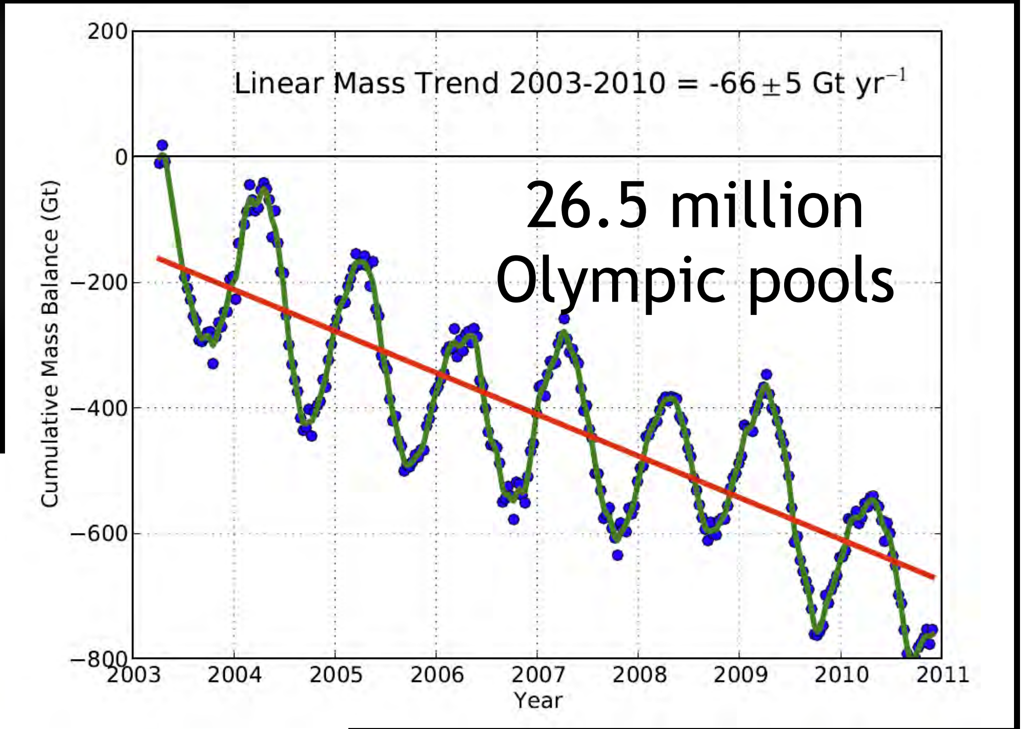


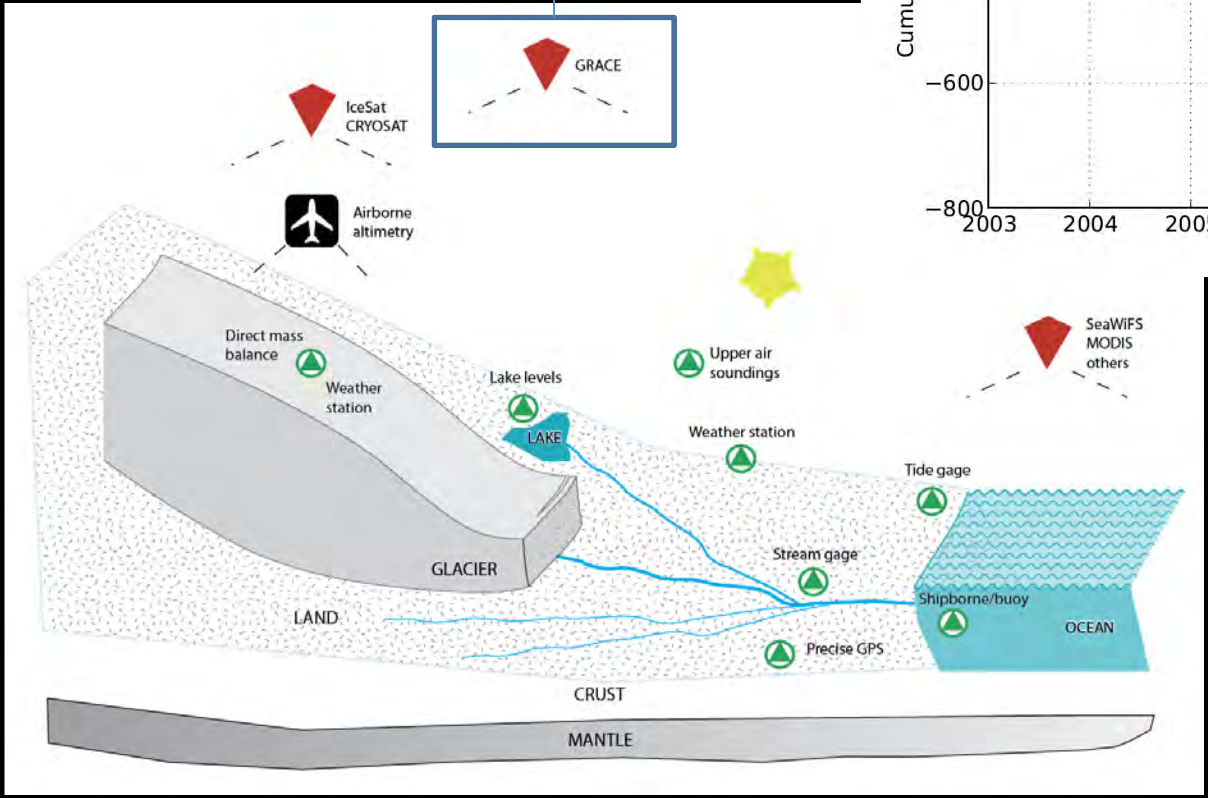


Temporal resolution: low
Spatial resolution: high
Spatial coverage: high

Satellite observations

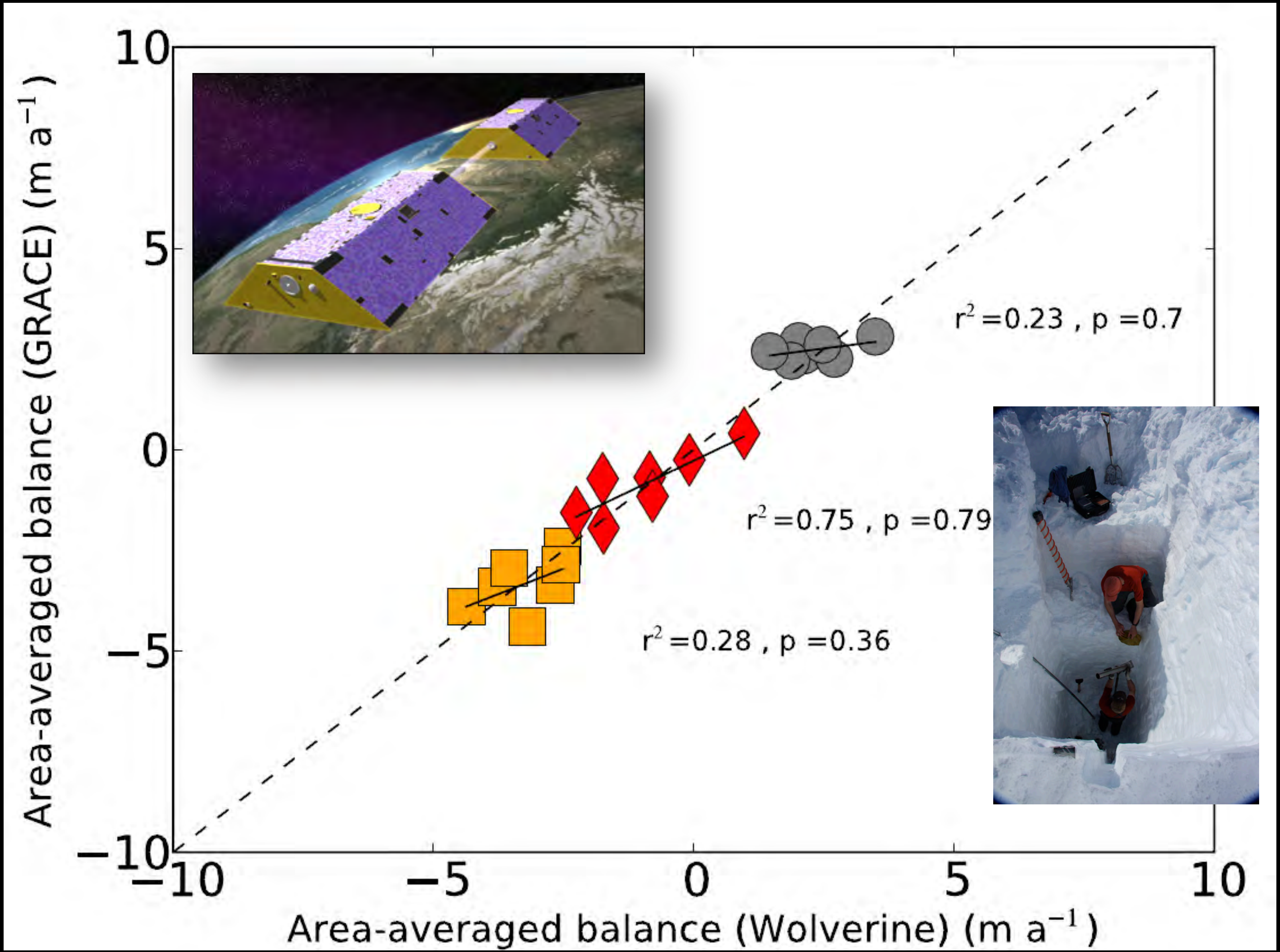




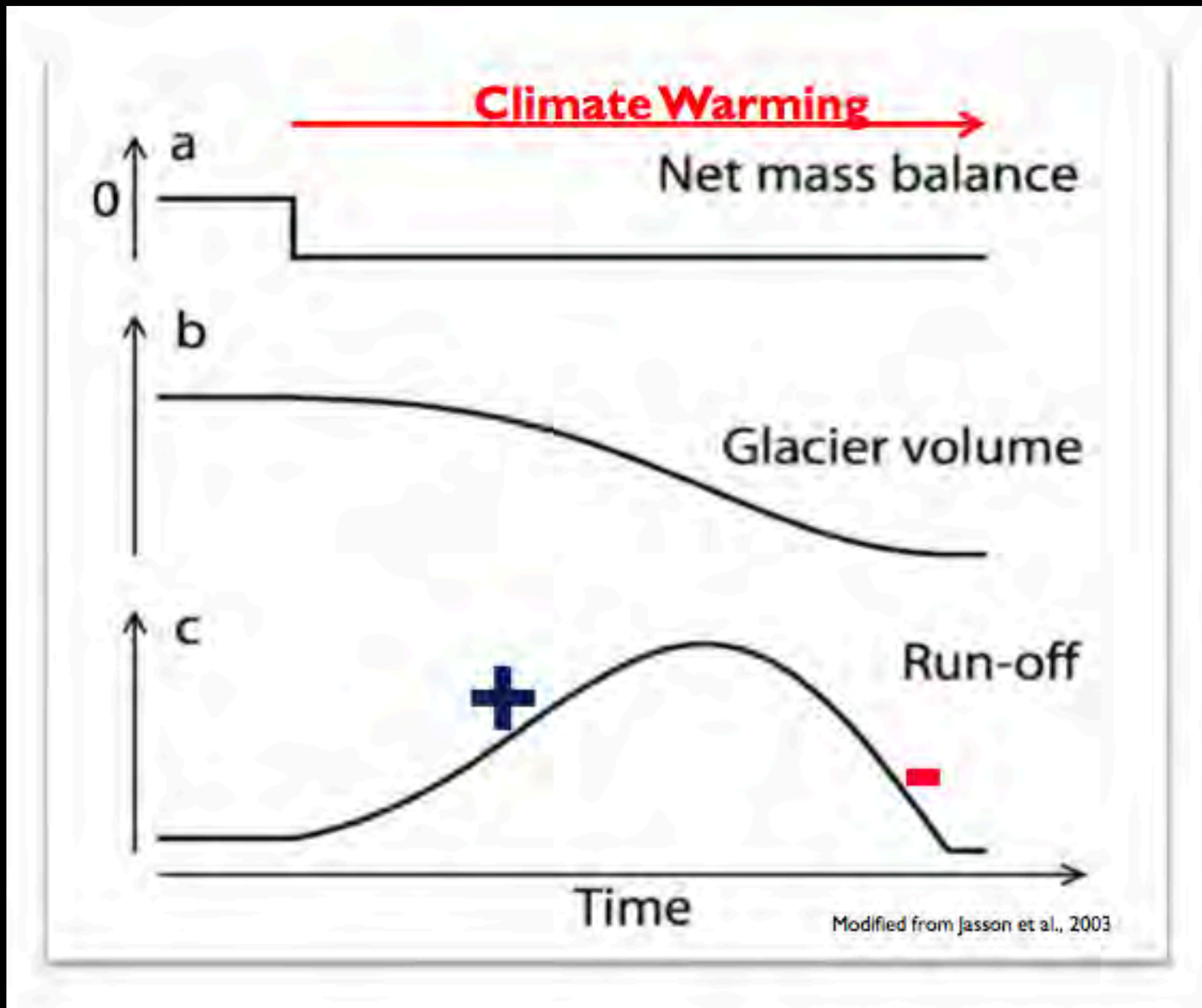


Temporal resolution: high
Spatial resolution: low
Spatial coverage: high

Comparing methods

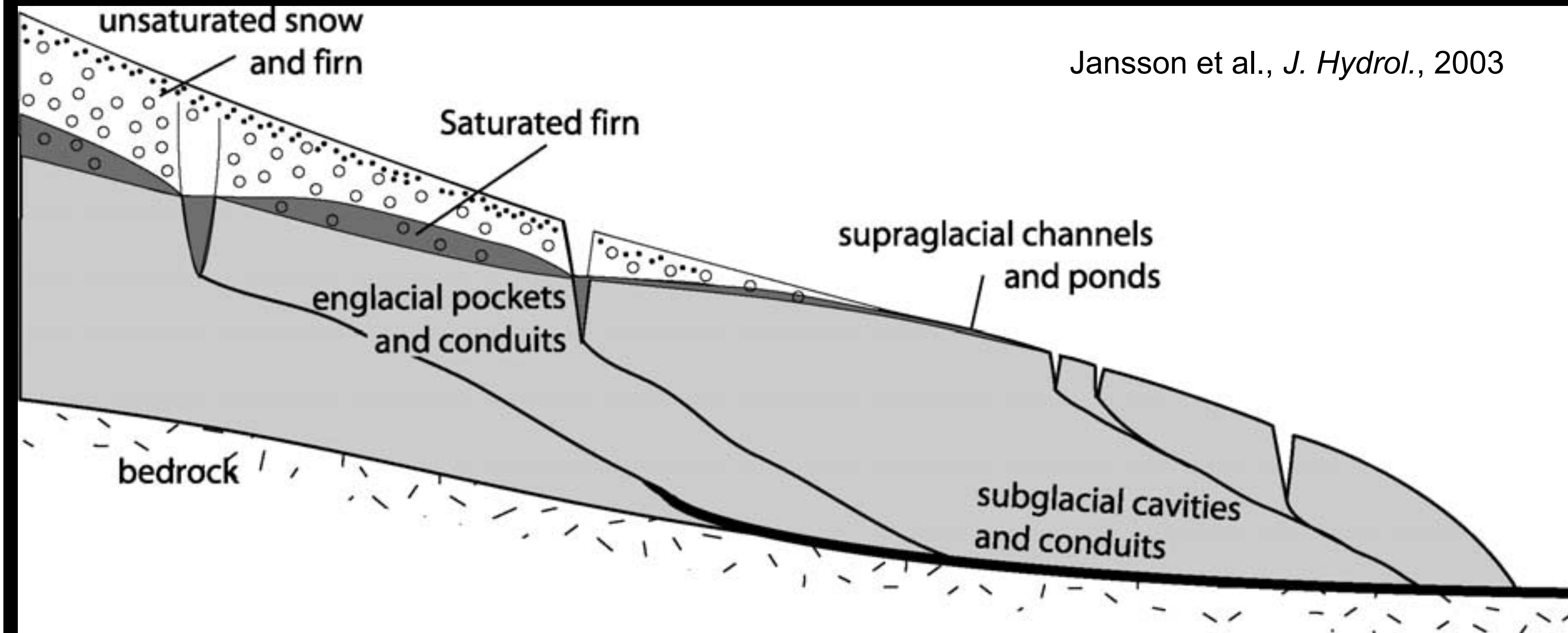


Glaciers, climate & runoff



Streamflow

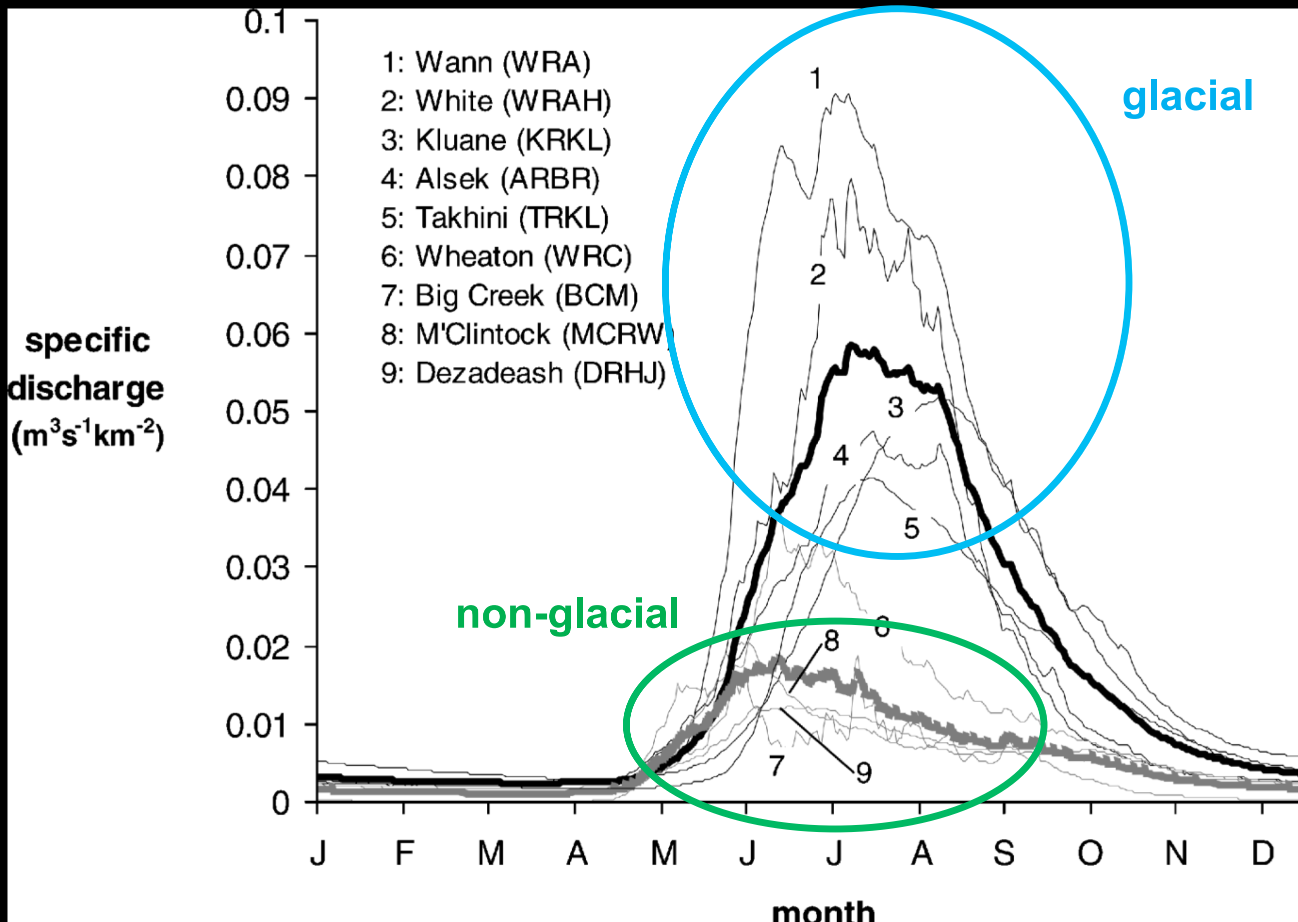
Water flow on and through glaciers



Jansson et al., *J. Hydrol.*, 2003

- Complex seasonal evolution
- Powerfully influences glacier dynamics
- Affects downstream flow: diurnal timing, seasonality

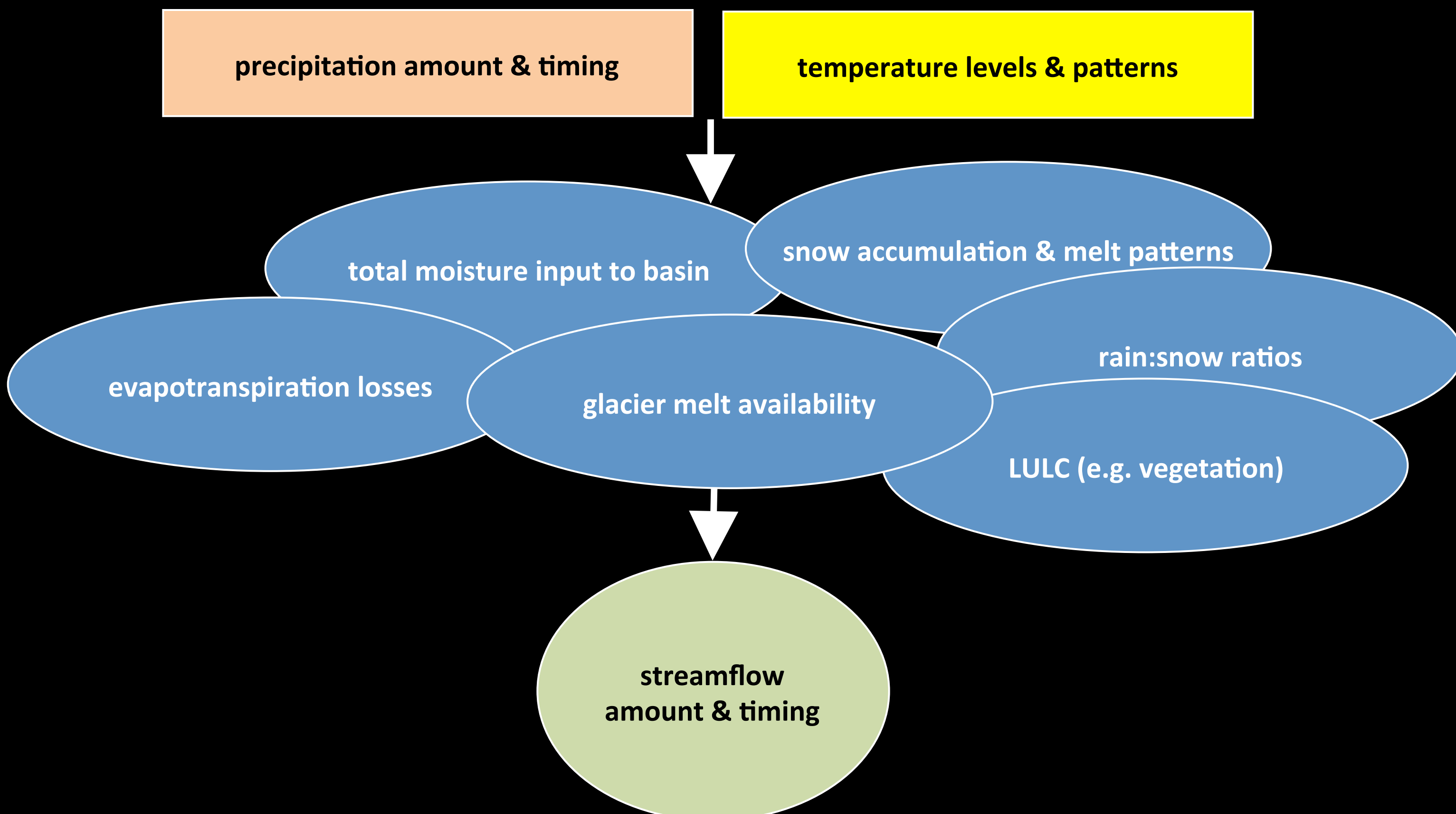
Glacier stream character



- Strong seasonal cycle
- Later, higher seasonal peak
- Driven by ice melt

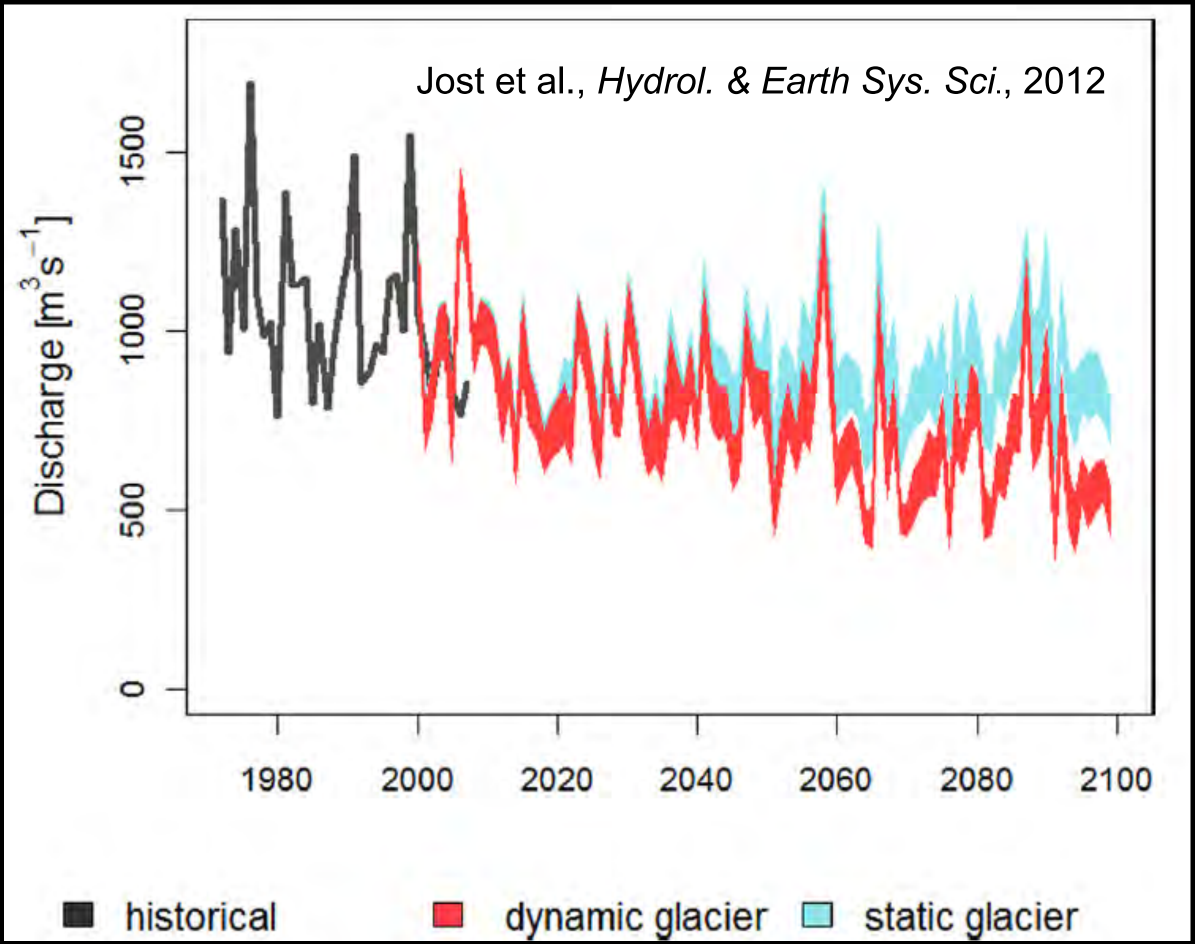
Glaciers, streamflow & climate change

- What will be the effects of potential future climatic changes on river flows?
- Multi-faceted problem
- Glaciers, and glacial responses to future climate, are an important element



Glaciers, streamflow & climate change

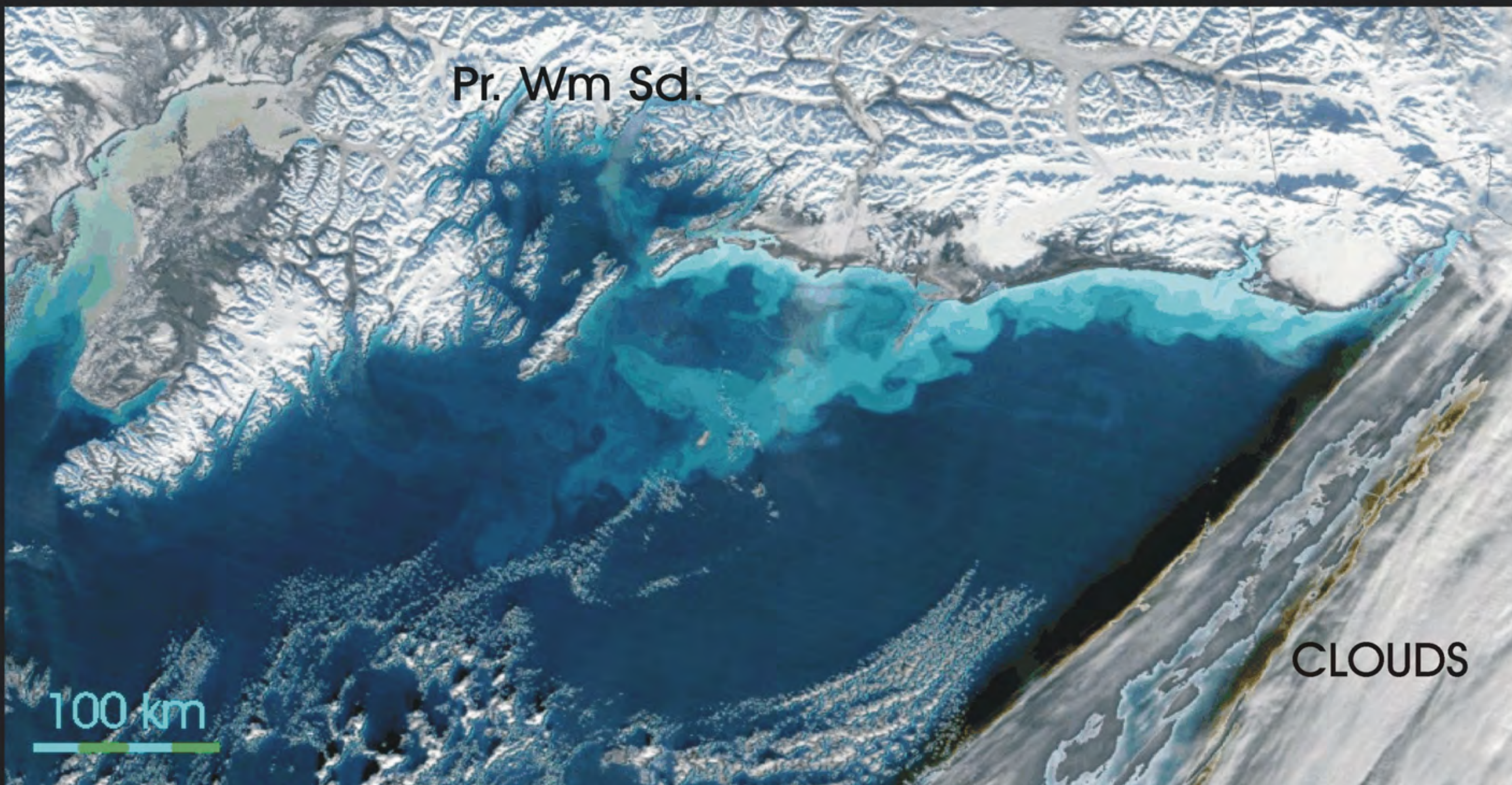
- Columbia River Mica Dam (5% glacierized)
- $3^{o}C$ warmer, 11% wetter
- Future glacier area updating used offline UBC EOS dynamical glacier model
- Two statistical downscaling methods used



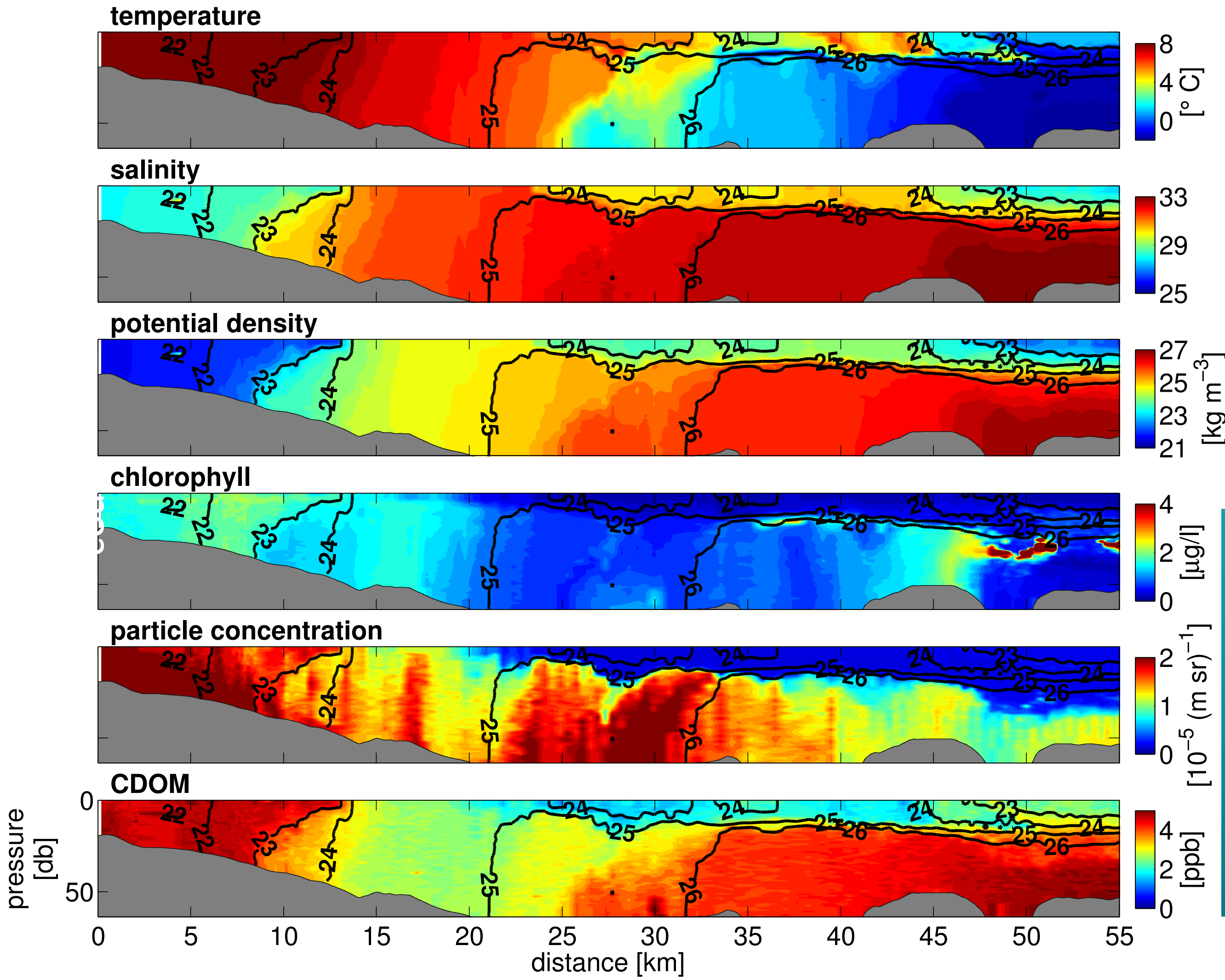
Five reasons why glaciers matter to rivers

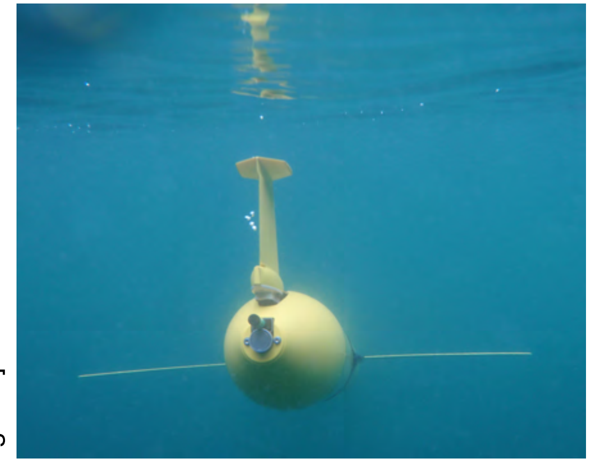
1) Even low levels of glacier cover alters streamflow
2) Unique response to climate change
3) Major control on timing and magnitude of streamflow
4) Major control on water quality
5) Strongly influence habitat quantity & quality

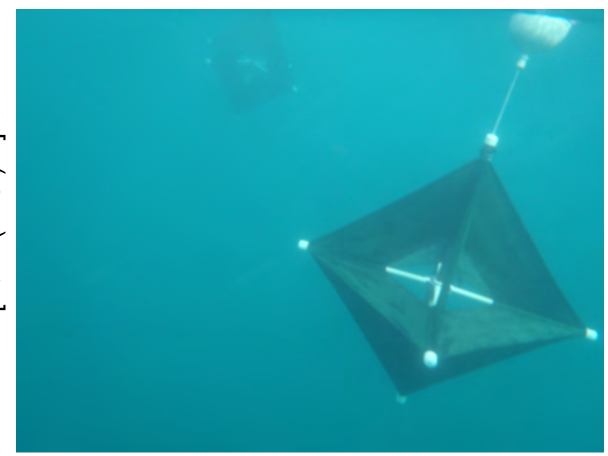
Oceanography



High dollar toys, amazing data

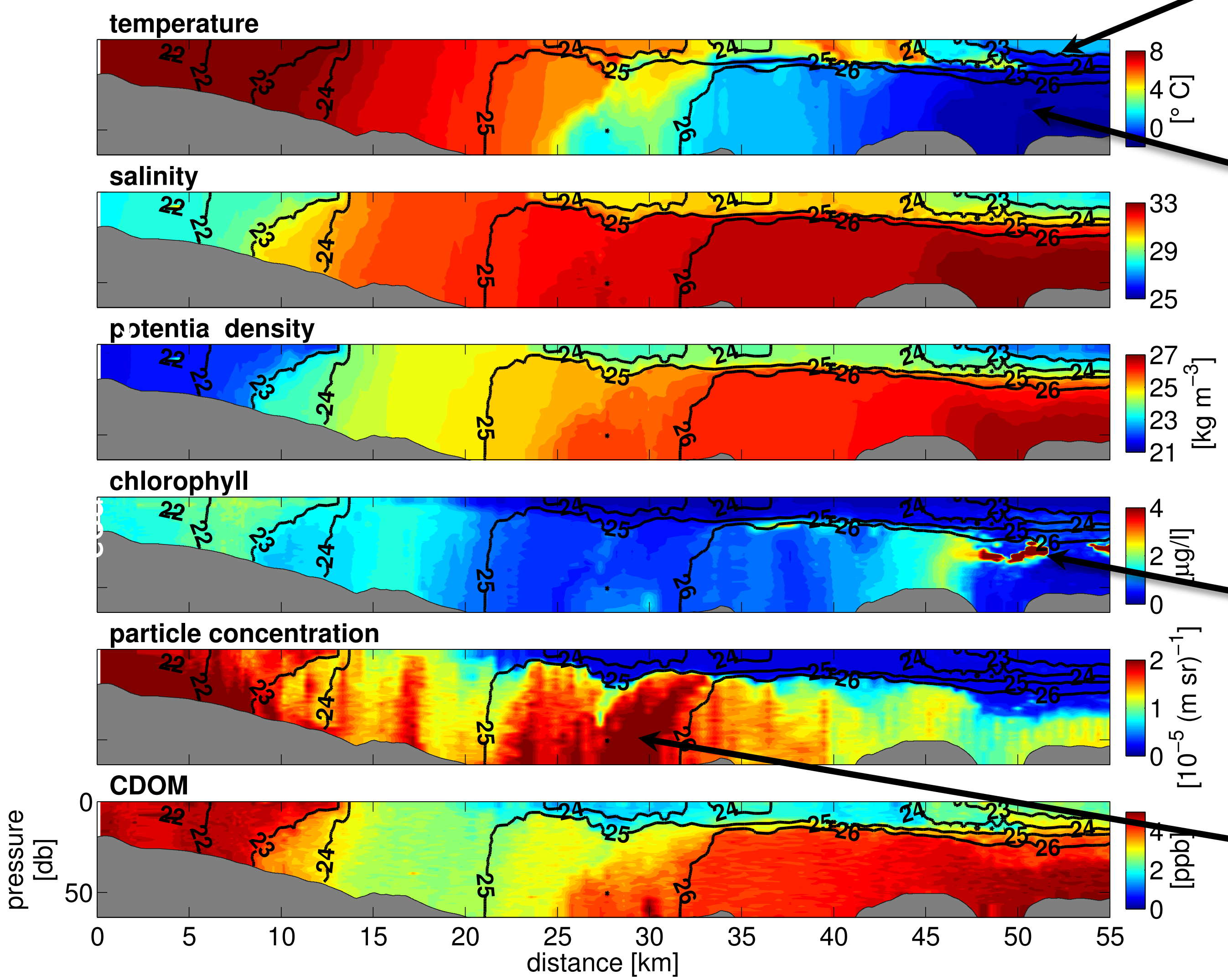






125 profiles over a 5-hour period

Nearshore ocean



Cold and fresh surface from ice melt

"cold pool"

Horizontal density fronts

Pyhtoplankton

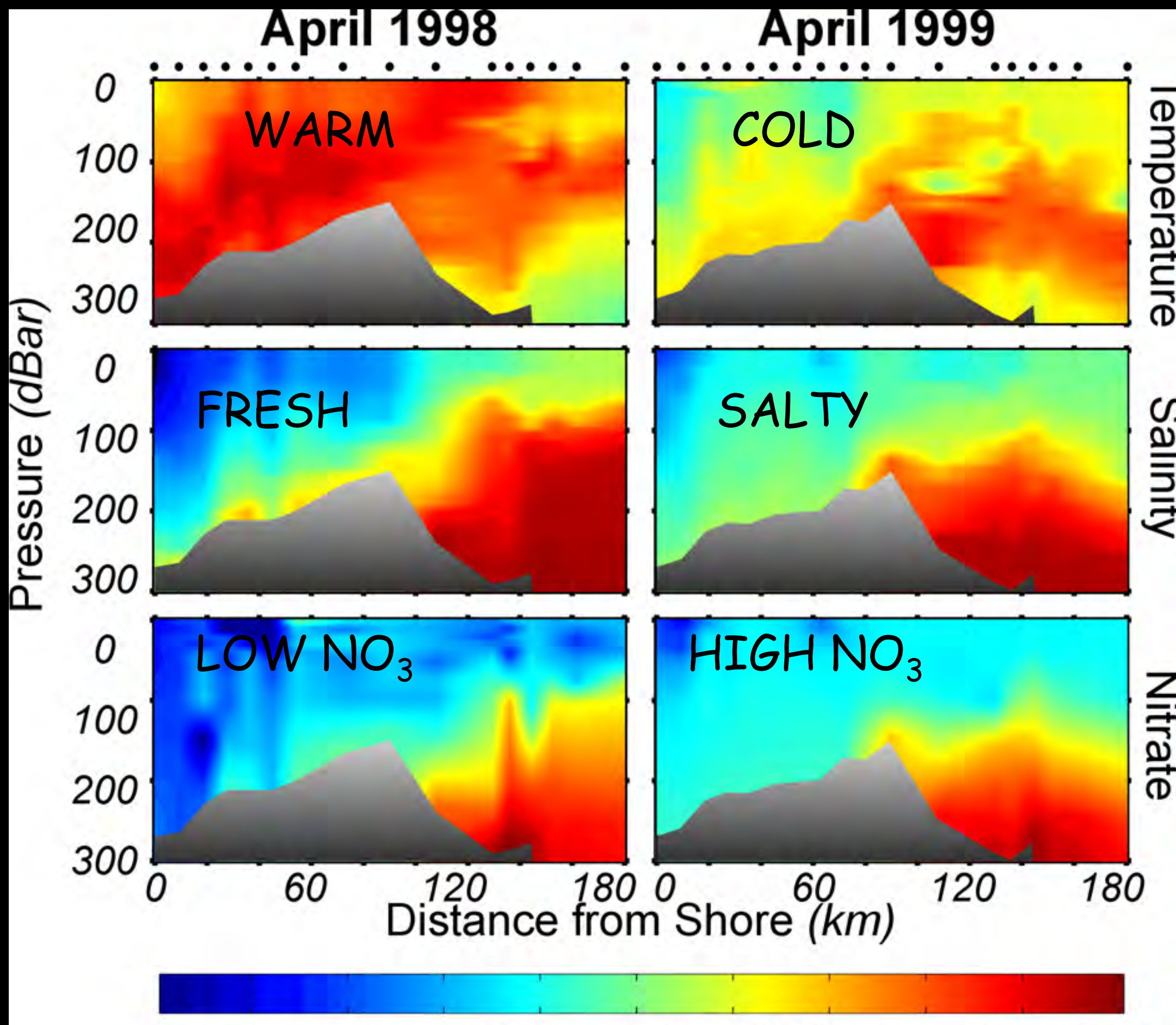
re-suspended sediment concentrations

Nearshore domain <15 m depth, rarely sampled.
Major pathway for fry and returning salmon

Time variability of the ocean

SEWARD ➡ OFFSHORE

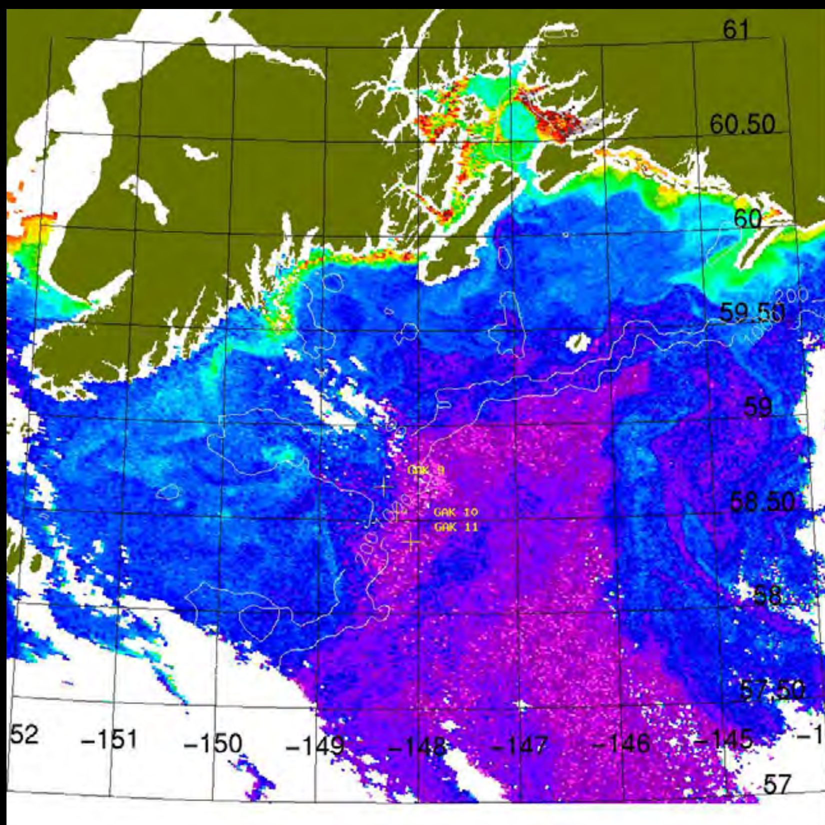
STRONGLY STRATIFIED



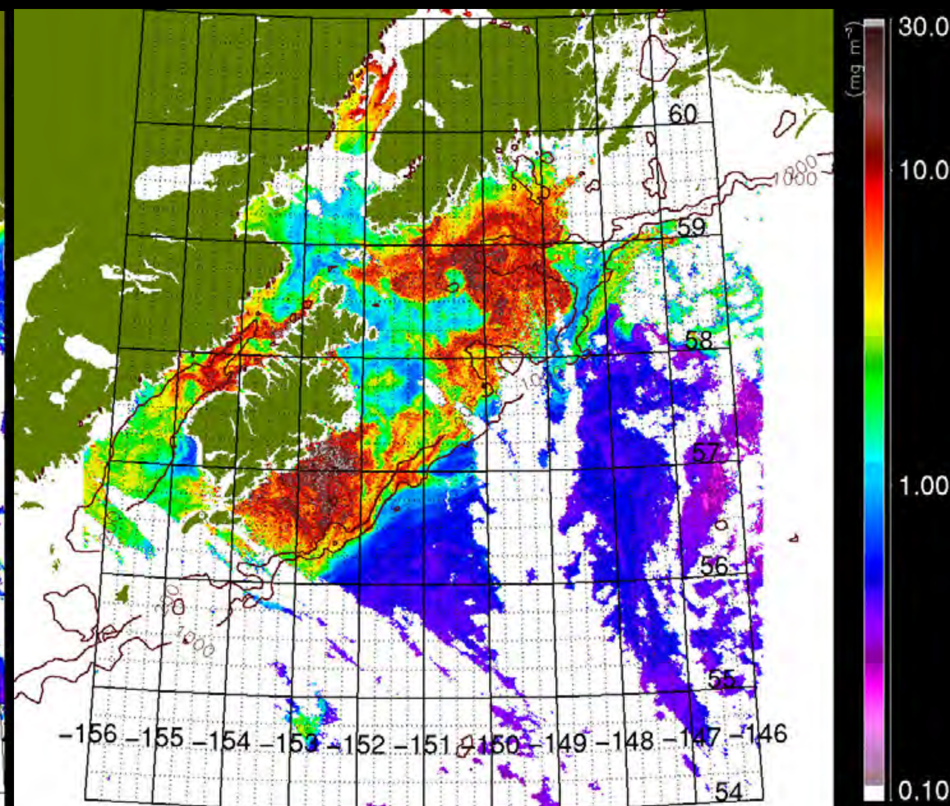
WEAKLY STRATIFIED

Primary productivity

April 1, 2003



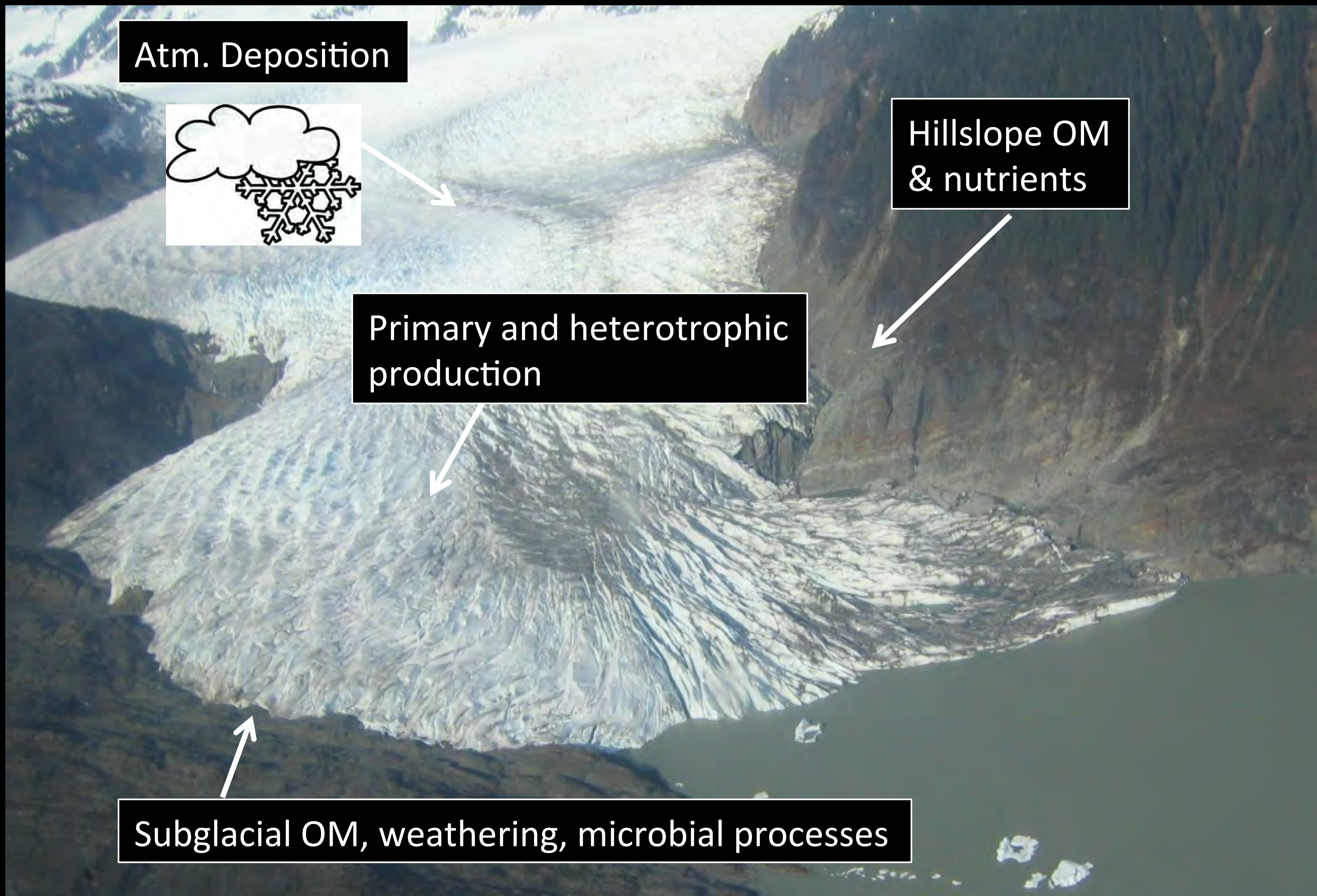
May 16, 2003



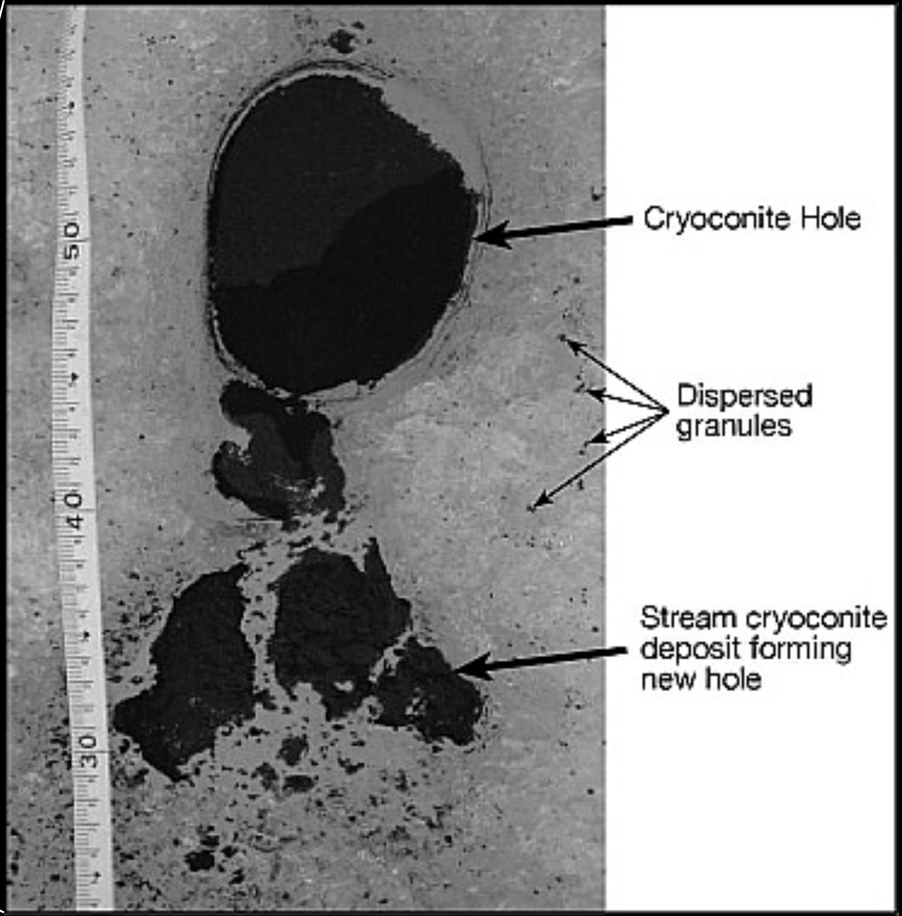
Primary production starts on the inner shelf and moves outwards due to different stratifying mechanisms.

Biogeochemistry

Glacier Ecosystems



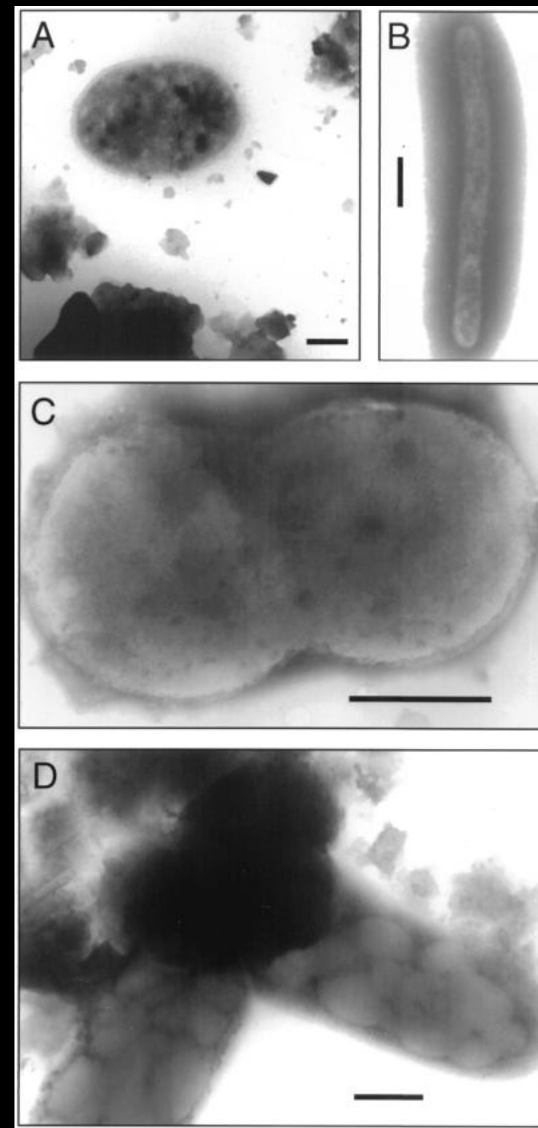
Supraglacial environment



- Atmospheric deposition of organic matter, nutrients and contaminants
- Microbial habitats in cryoconite holes, deposits, and streams

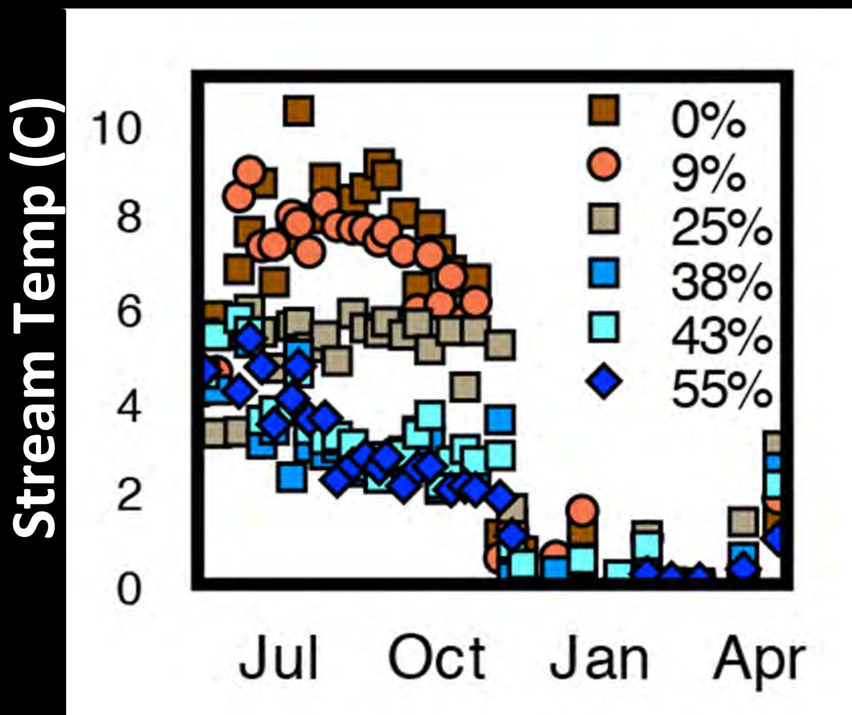
Subglacial biogeochemistry

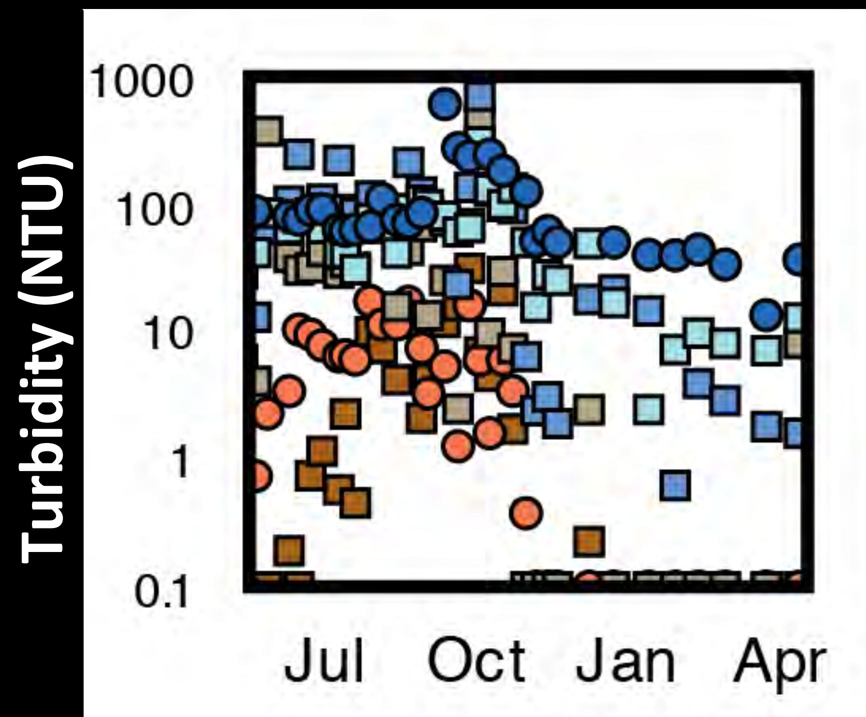
- Abundant microbial communities at the till/ice interface
- Inputs from supraglacial environments
- Processing of organic material and nutrients before export to rivers



Skidmore et al., 2000, App. Env. Microbiol

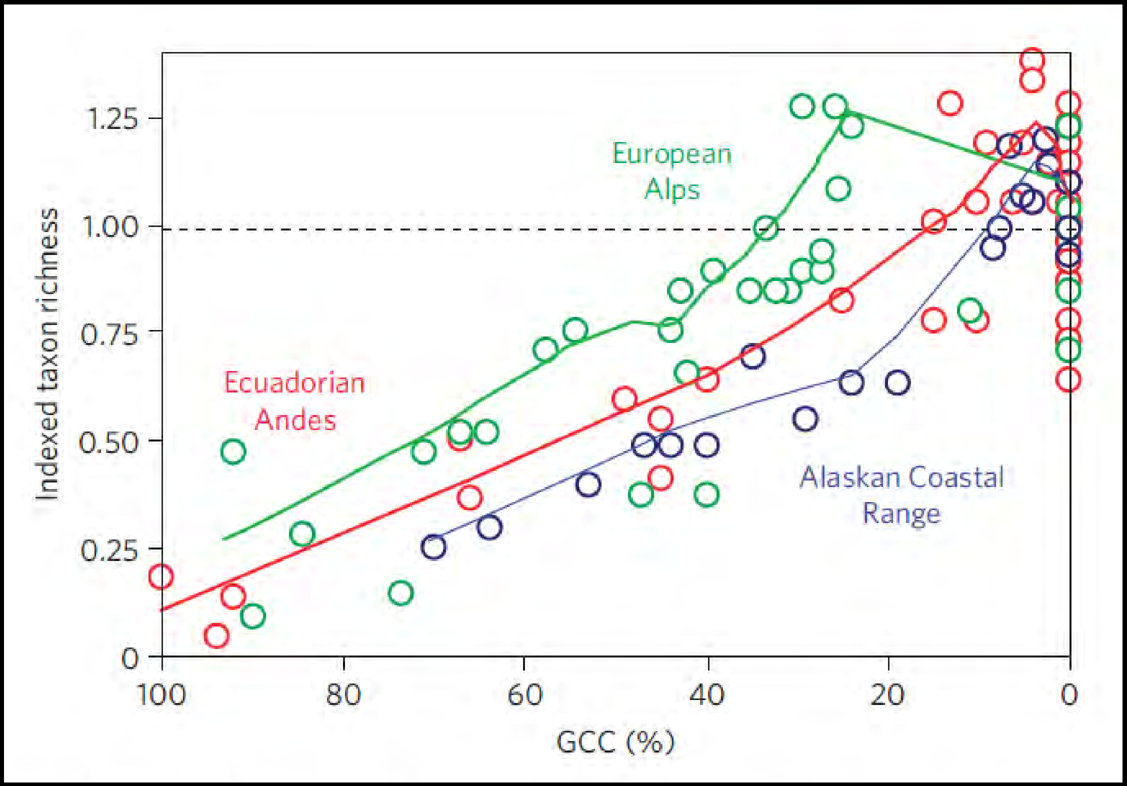
Physical properties of rivers





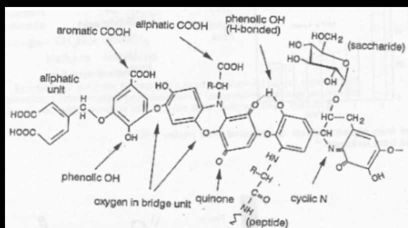
Hood and Berner, 2009, JGR

Riverine Biodiversity

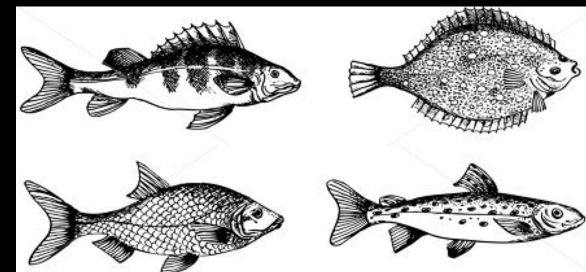


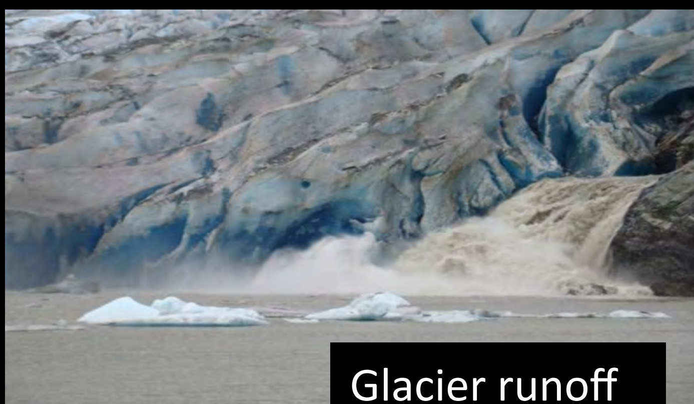
Jacobsen et al., 2012, Nature Climate Change

Glacier organic carbon



Base of the aquatic food web





Glacier runoff

DOC export = 12-18 kg C/ha/yr

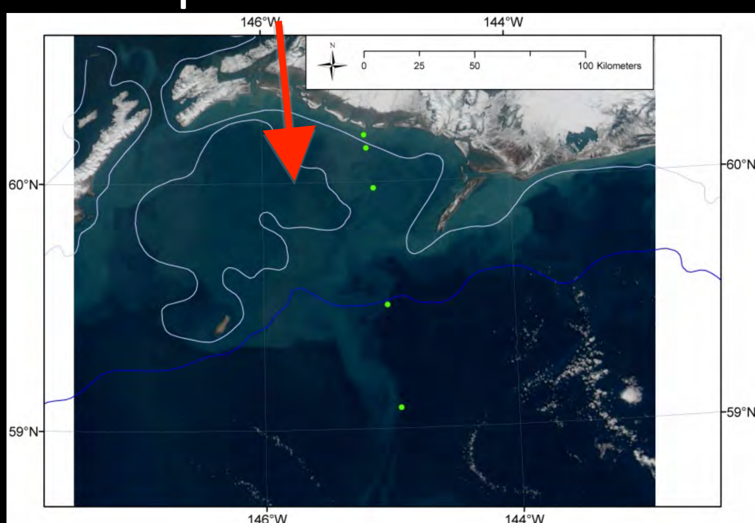
Boreal forests

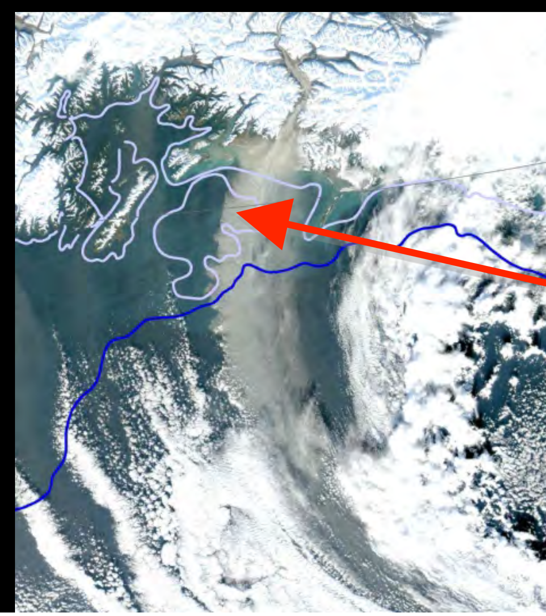
DOC export = 22-86 kg C/ha/yr

Glaciers as a Marine Fe Source

Glacier River Plumes

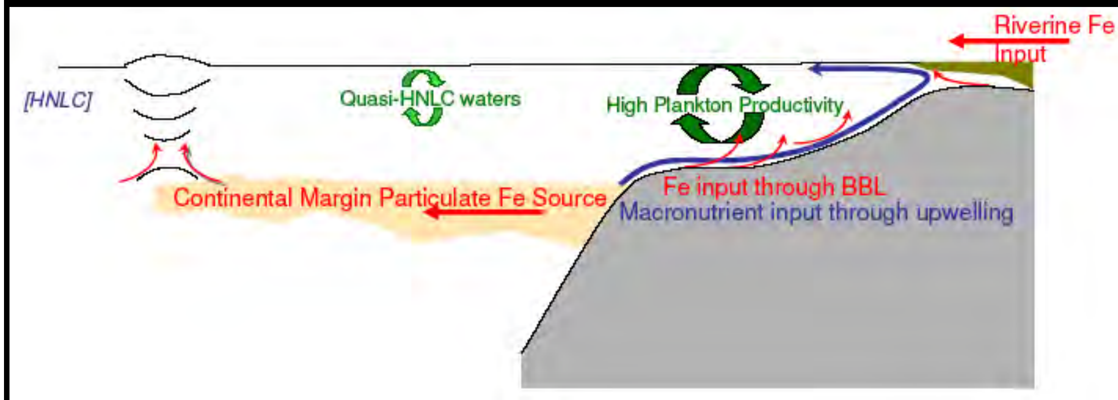
Resuspended Glacial Flour

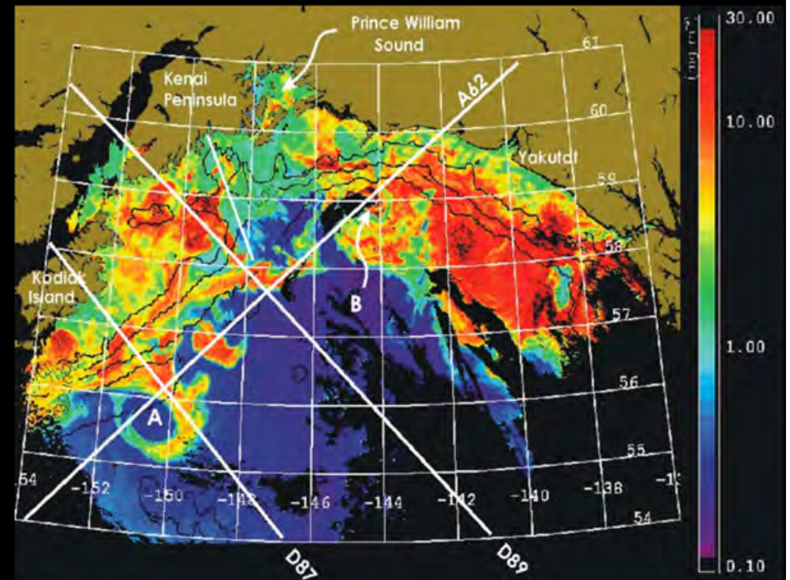




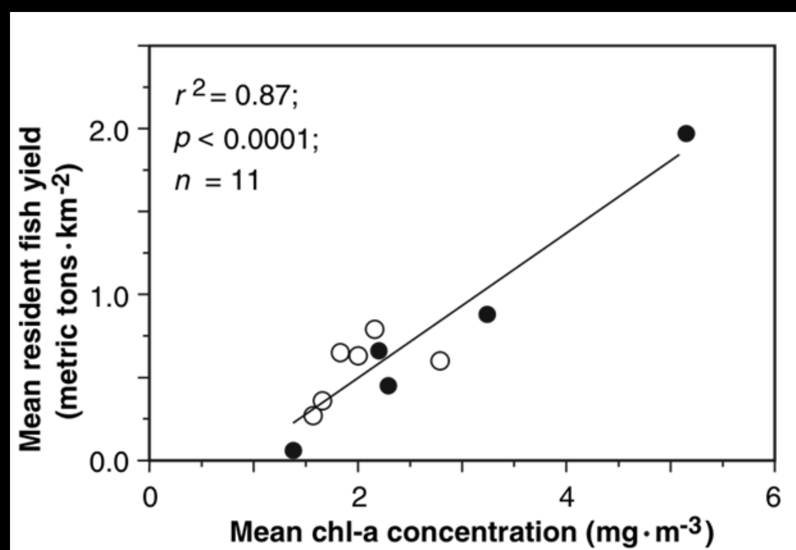
Dust Storms

Coastal Mixing of Riverine Fe and Marine Nitrate





Ample nutrients drive productivity and fisheries



Glacier Contaminants

Blast from the Past: Melting Glaciers as a Relevant Source for Persistent Organic Pollutants

CHRISTIAN BOGDAL,*,†,‡
PETER SCHMID,‡ MARKUS ZENNEGG,‡
FLAVIO S. ANSELMETTI,§
MARTIN SCHERINGER,† AND
KONRAD HUNGERBÜHLER†

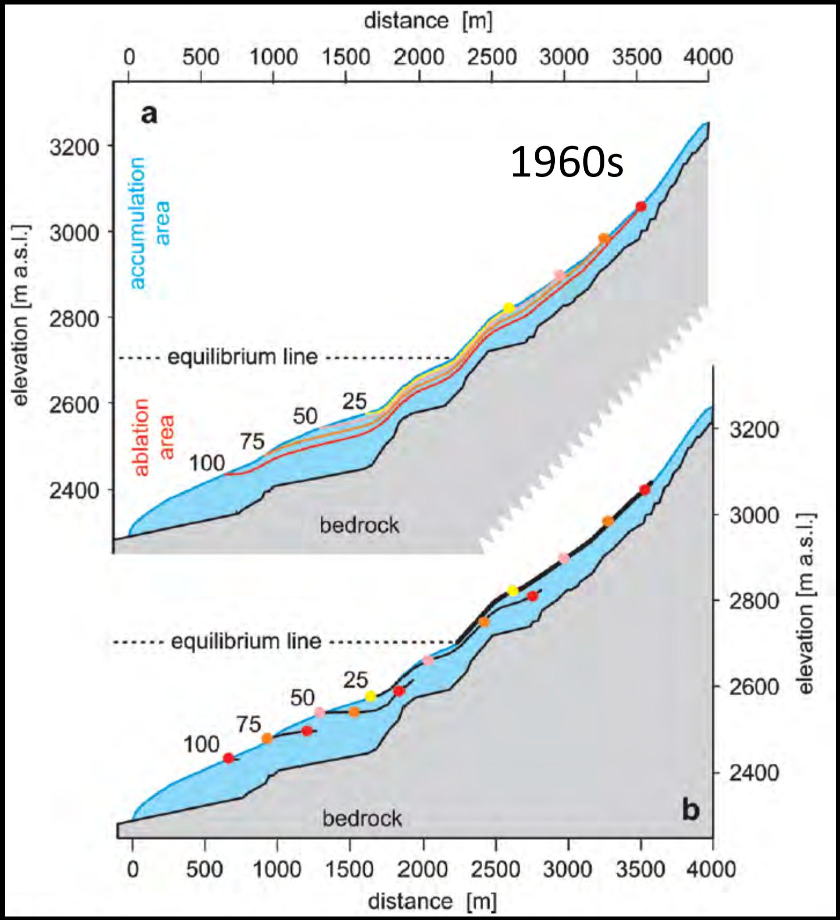
Institute for Chemical and Bioengineering, ETH Zurich, Wolfgang-Pauli-Strasse 10, CH-8093 Zürich, Switzerland, Empa, Swiss Federal Laboratories for Materials Testing and Research, Überlandstrasse 129, CH-8600 Dübendorf, Switzerland, Eawag, Swiss Federal Institute of Aquatic Science and Technology, Überlandstrasse 133, CH-8600 Dübendorf, Switzerland

Melting Glaciers: A Probable Source of DDT to the Antarctic Marine Ecosystem

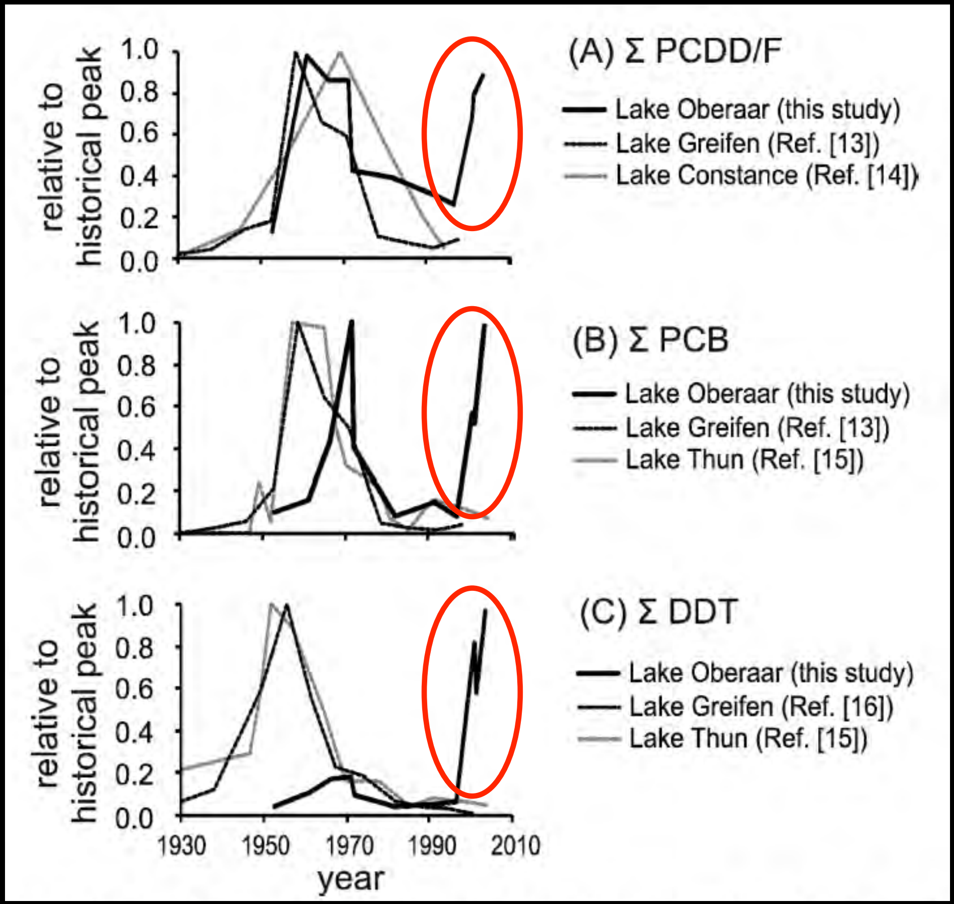
HEIDI N. GEISZ,*
REBECCA M. DICKHUT,
MICHELE A. COCHRAN,
WILLIAM R. FRASER,† AND
HUGH W. DUCKLOW‡

Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062, Polar Oceans Research Group, Sheridan, Montana 59749, and Ecosystems Center, Marine Biological Laboratory, Woods Hole, Massachusetts 02543

Dynamics of Contaminant Release

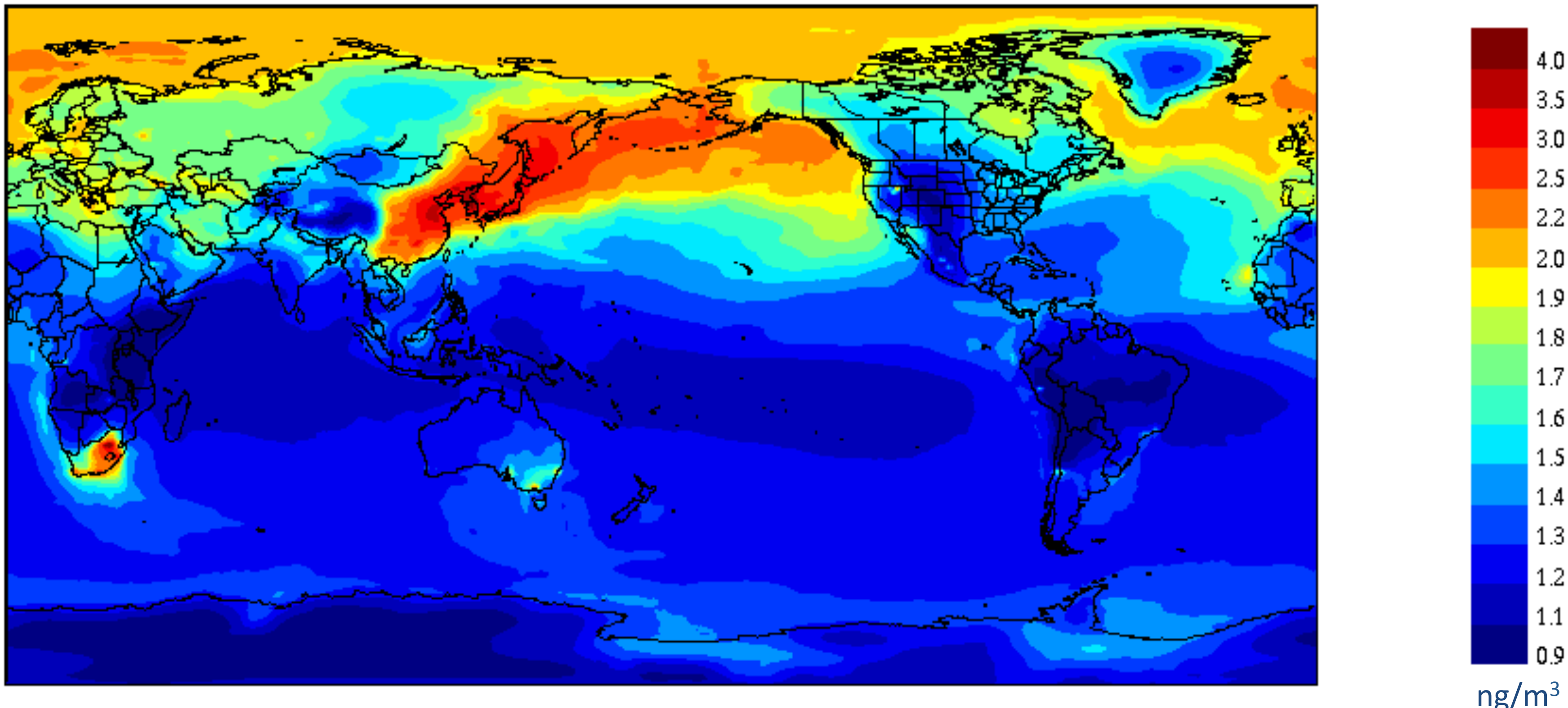


Bogdal et al., 2010, ES&T



Bogdal et al., 2009, ES&T

Atmospheric models show Hg transport to Alaska



July, 2001

GRAHM (Global/Regional Atmospheric Heavy Metals Model) simulation – Ashu Dastoor, Meteorological Service of Canada,Environment Canada

Runoff from glaciers is unique amongst terrestrial ecosystems:

- bioavailable organic matter
- nutrients (P)
- micronutrients (Fe)
- contaminants (Hg)

Ecology

Harbor Seals

- High fidelity to glacial habitat
- Glaciers provides refuge from predation
- Glacial-born pups have short weaning times

Blundell *et al.* 2011, Herreman *et al.* 2009, Womble *et al.* 2010

Seabirds feed at glacier termini

Diving seabirds forage on upwelled crustaceans

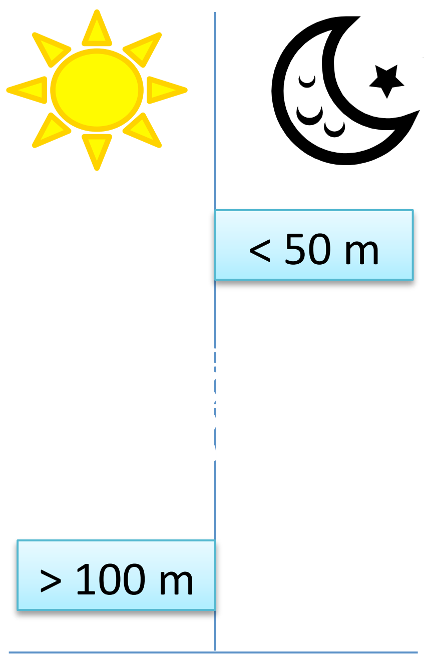
- Upwelling submarine glacier discharge makes for abundant food
- Mixing caused by calving
- Mortality of zooplankton caused by osmotic shock
- Seasonality coincides with breeding effort in seabirds

Mehlum and Gabrielsen 1993

Ecological patterns in glacier-marine ecosystems

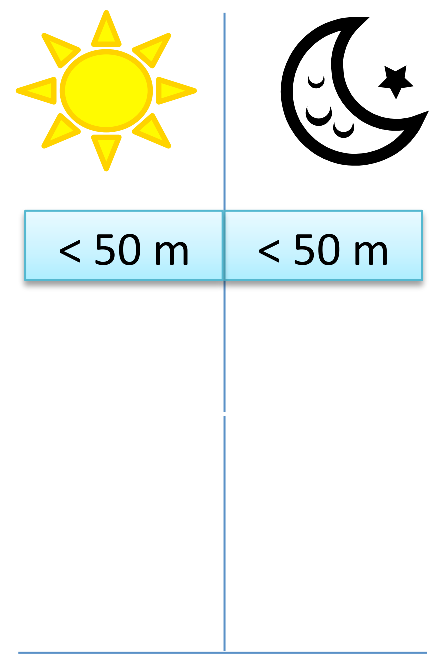
Absence of light changes vertical migration

In Clear Water



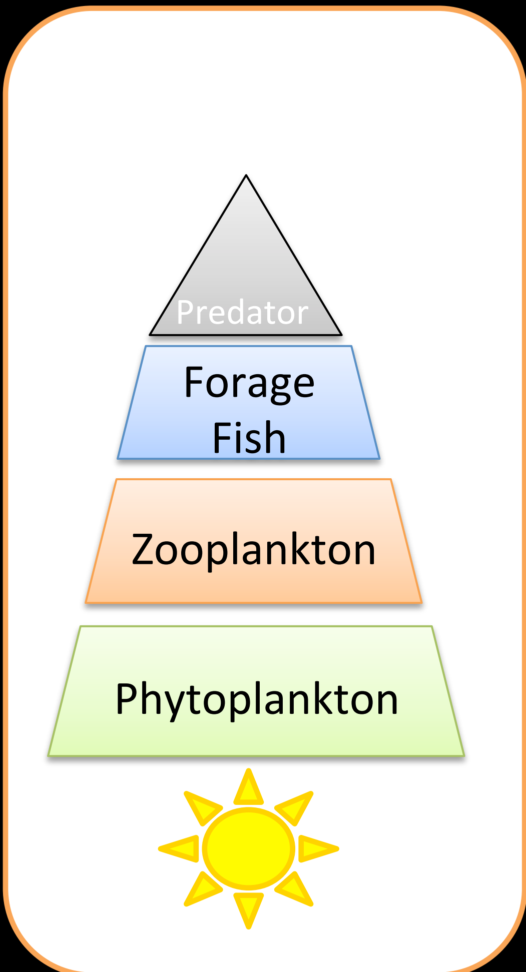
Mesopelagic species in near-surface waters during daylight hours

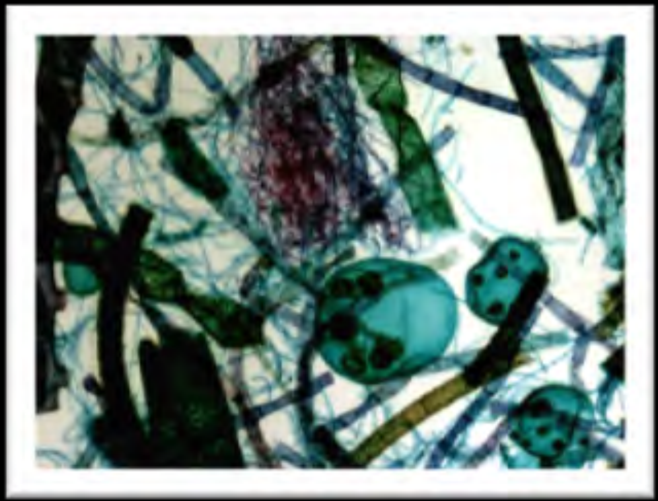
In Sediment-Laden Water

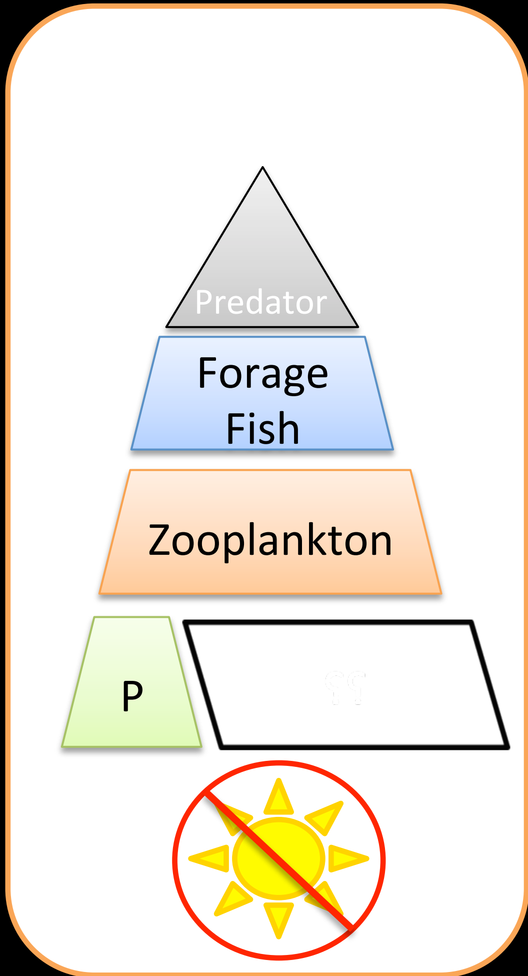


Glacier-marine food webs

High sediment load limits light availability to phytoplankton

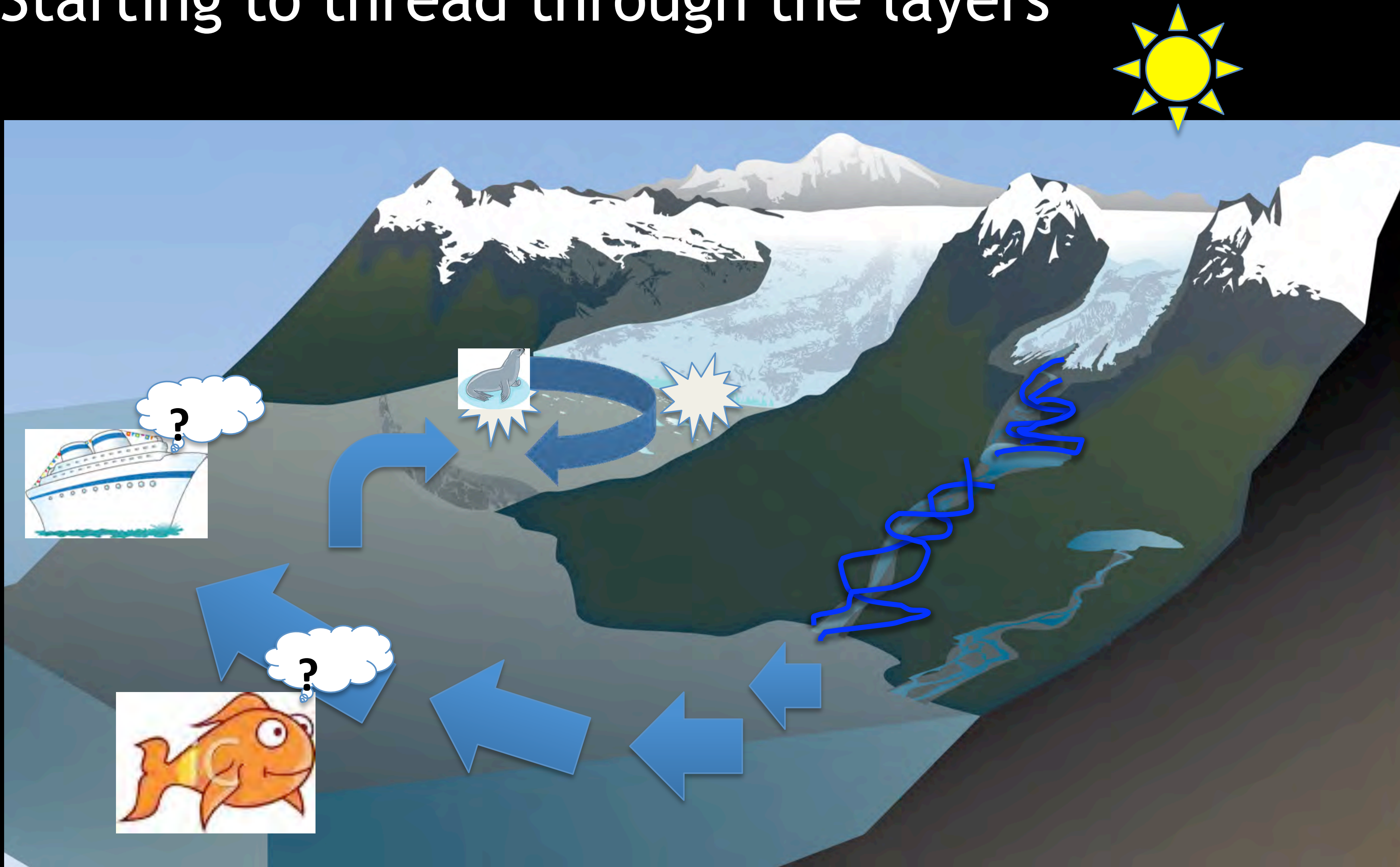







Summary

Starting to thread through the layers



Glaciers influence the entire ecosystem

- Glaciers are vibrant ecosystems
- Influence streamflow volume, seasonality and variability
- Downstream nutrient supply via meltwater
- AK coastal current driven by freshwater from glaciers
- Freshwater and marine food webs influenced by glaciers
- Glacier change will have economic impacts on fisheries, hydropower & tourism